Ministerie van Verkeer en Waterstaat

Rijkswaterstaat

Wind input for the assessment of storm surges and waves

modeling methodologies session

J.P. (Hans) de Waal

5 juli 2006

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2. Physics: Wind, water levels and waves
3. Physics: Wind data and surface roughness
4. Physics: Air-sea interaction: wind drag
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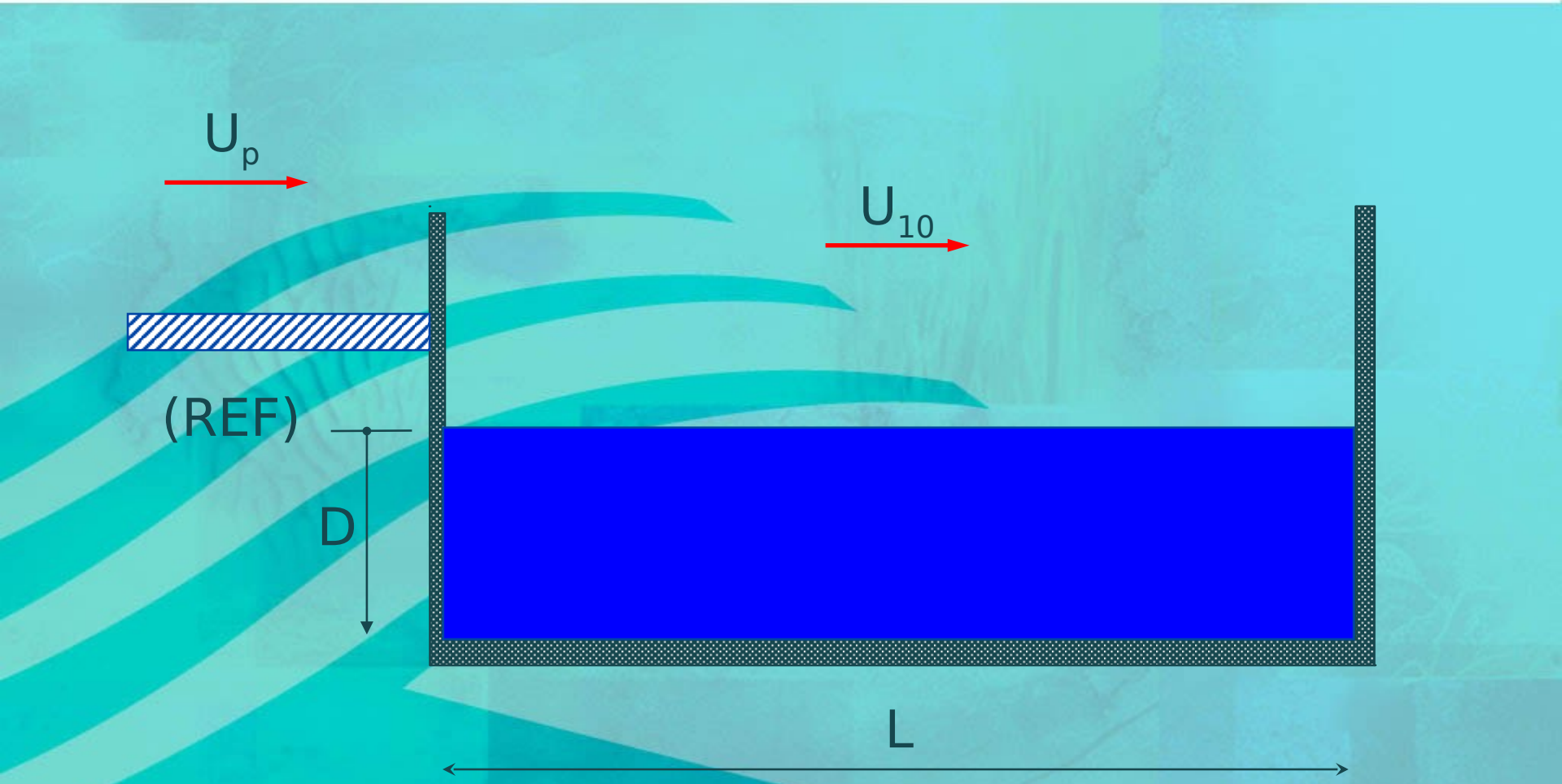
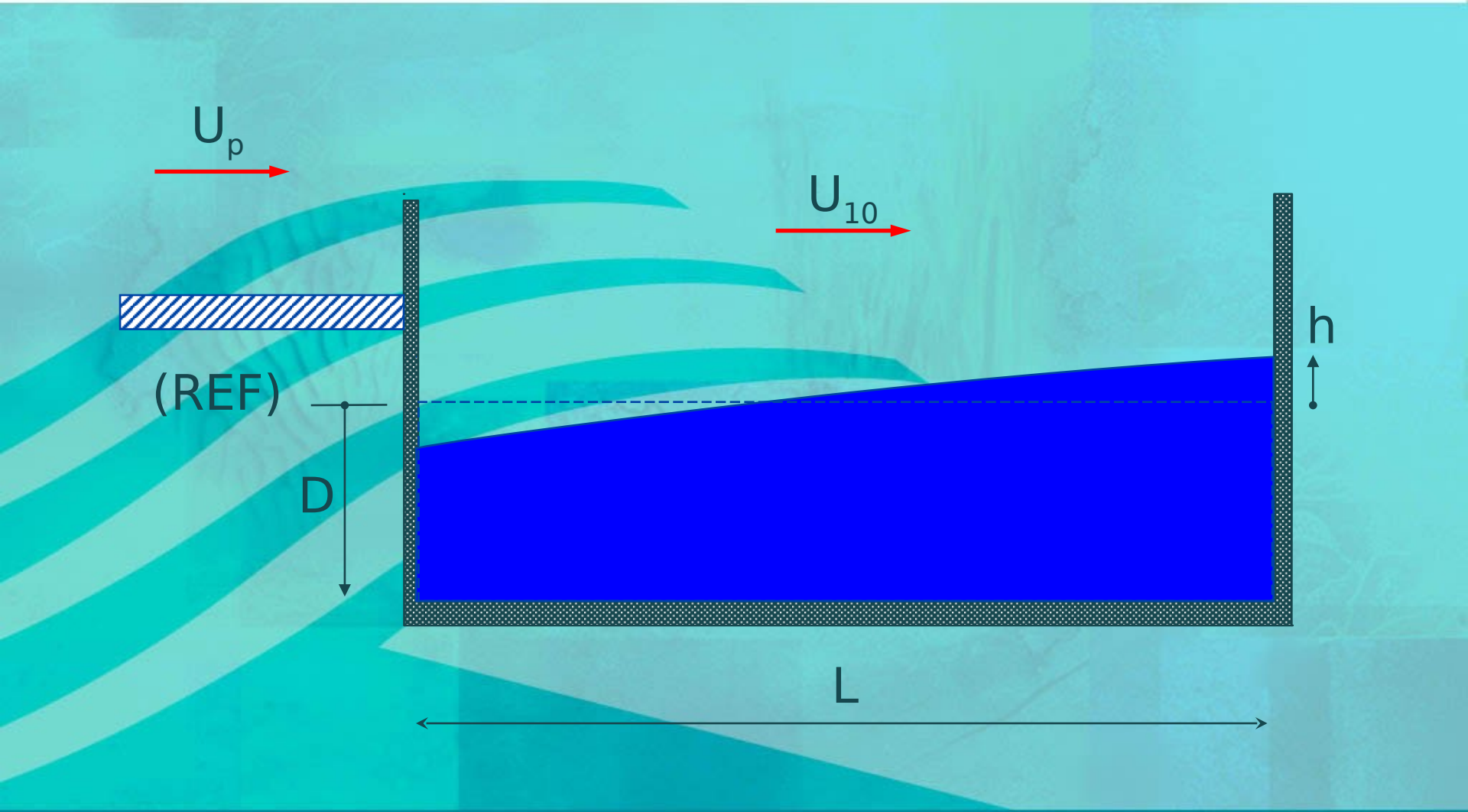
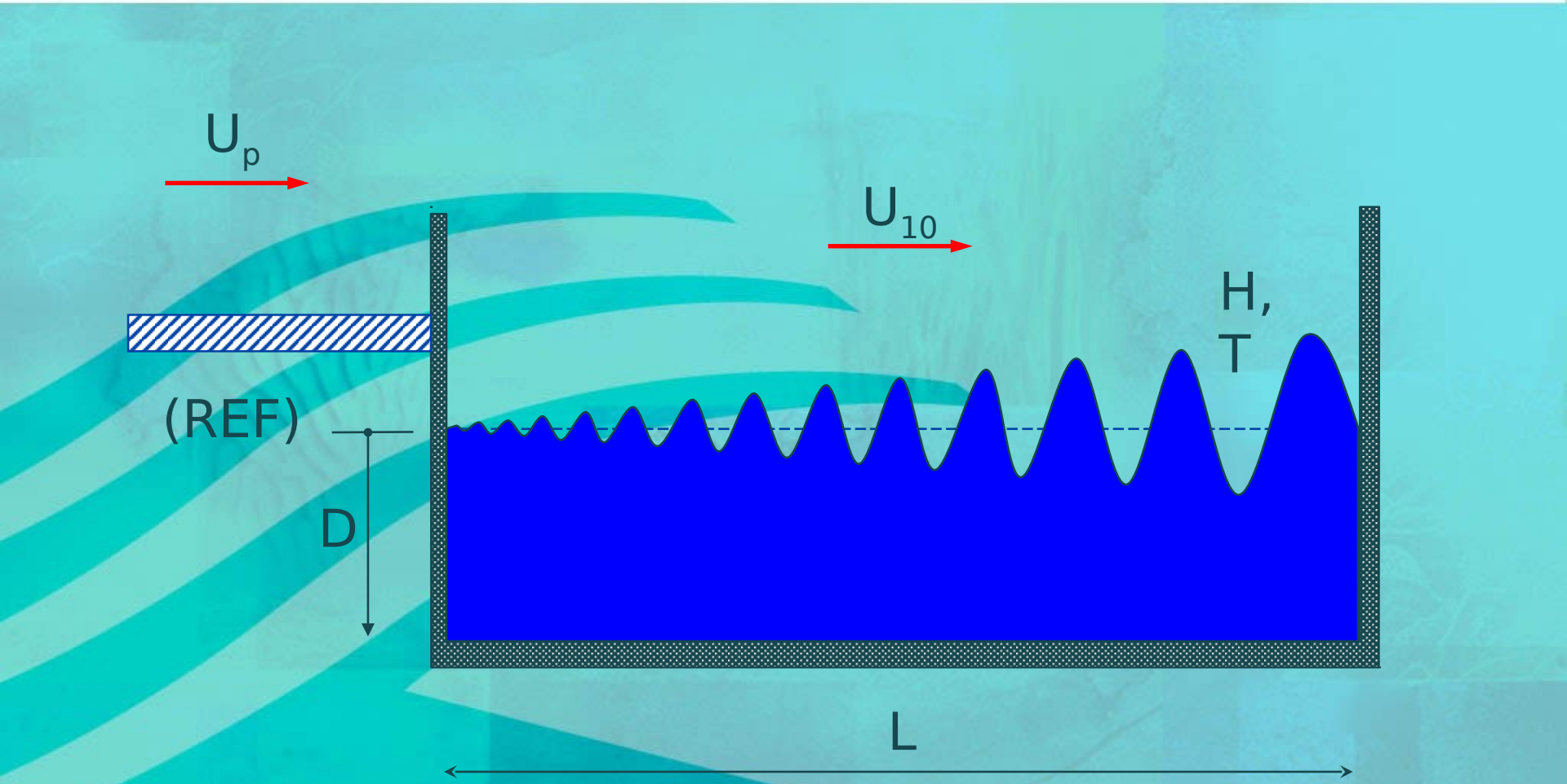
Wind over land and water



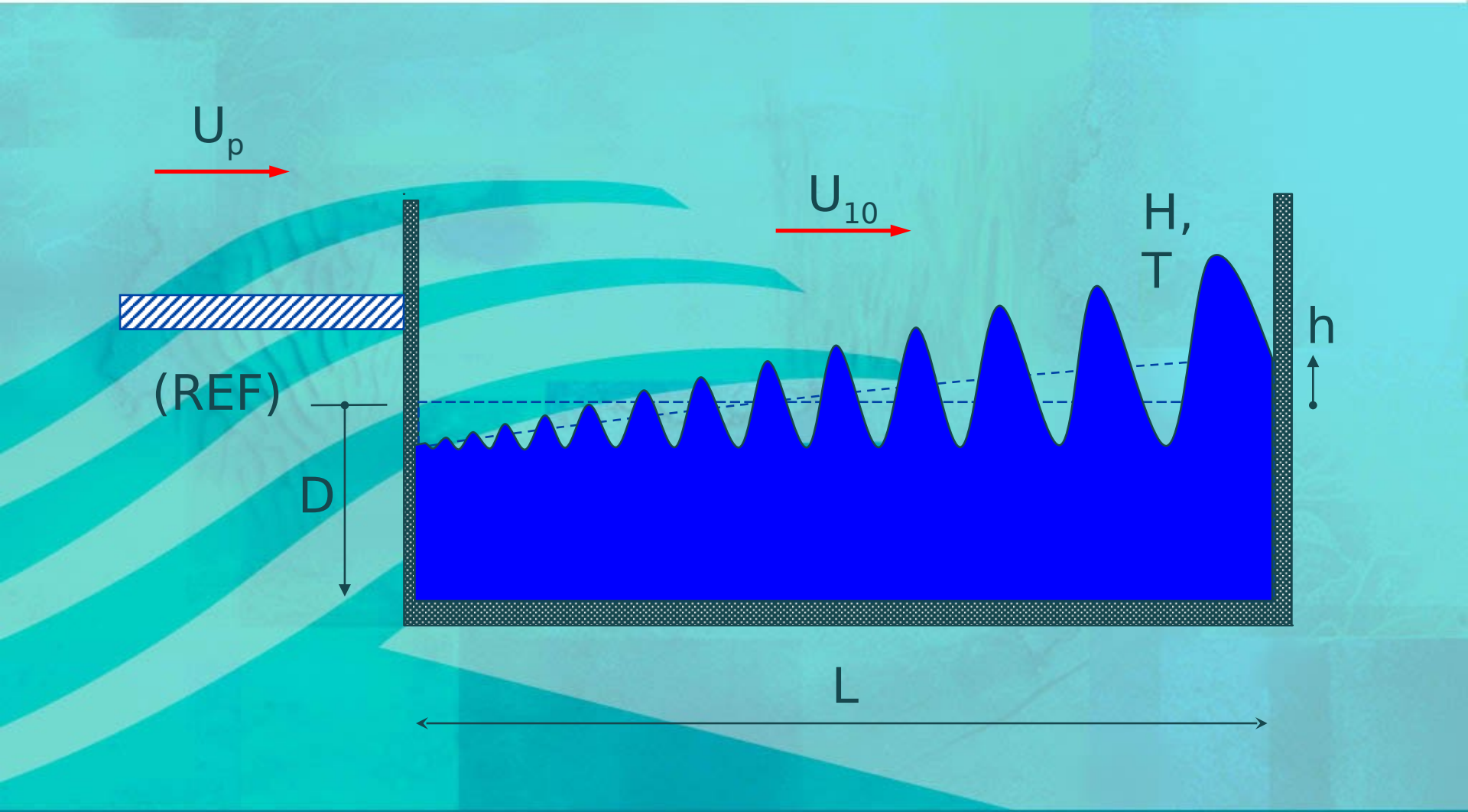
Wind setup and setdown



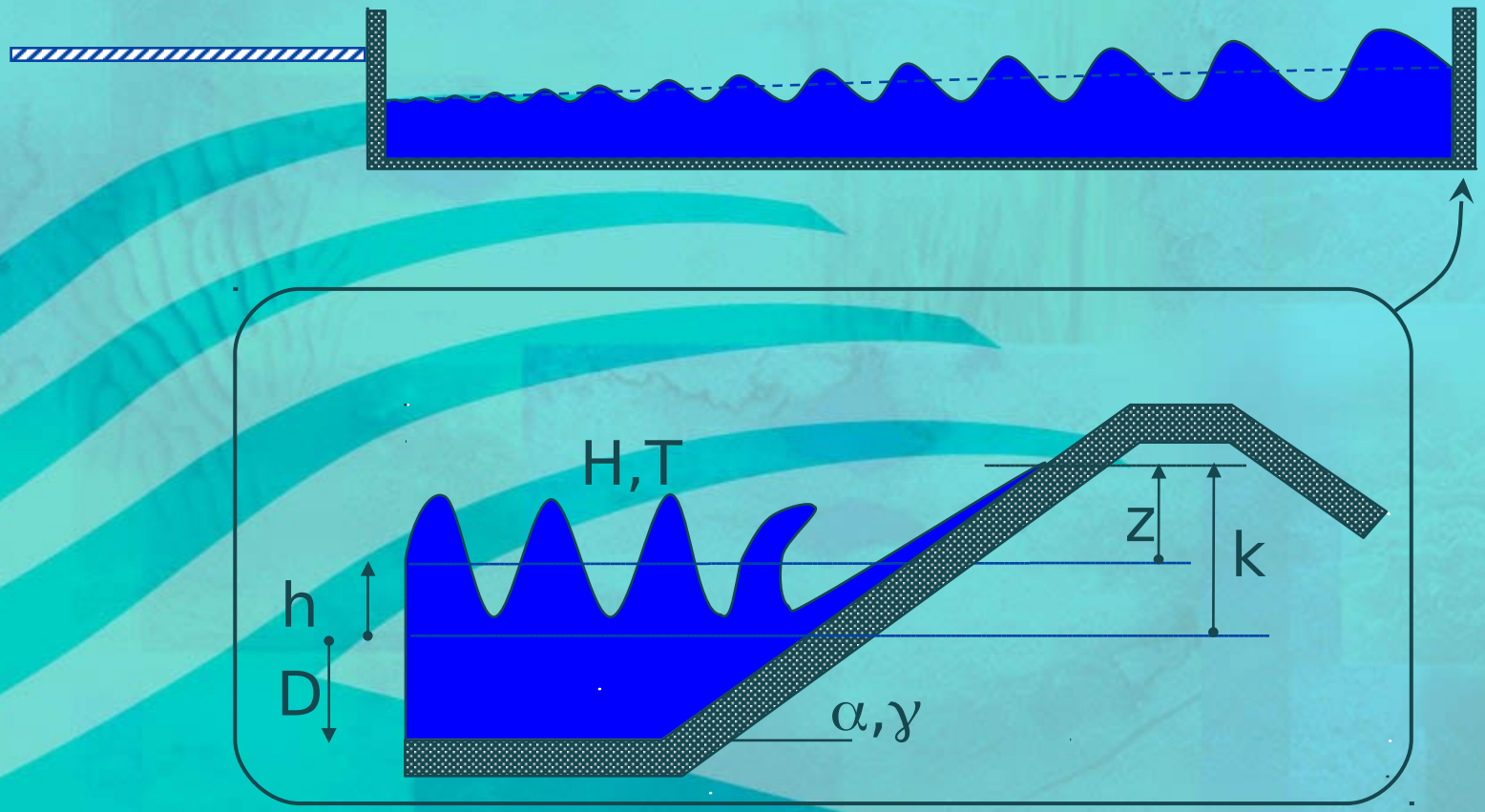
Wave growth



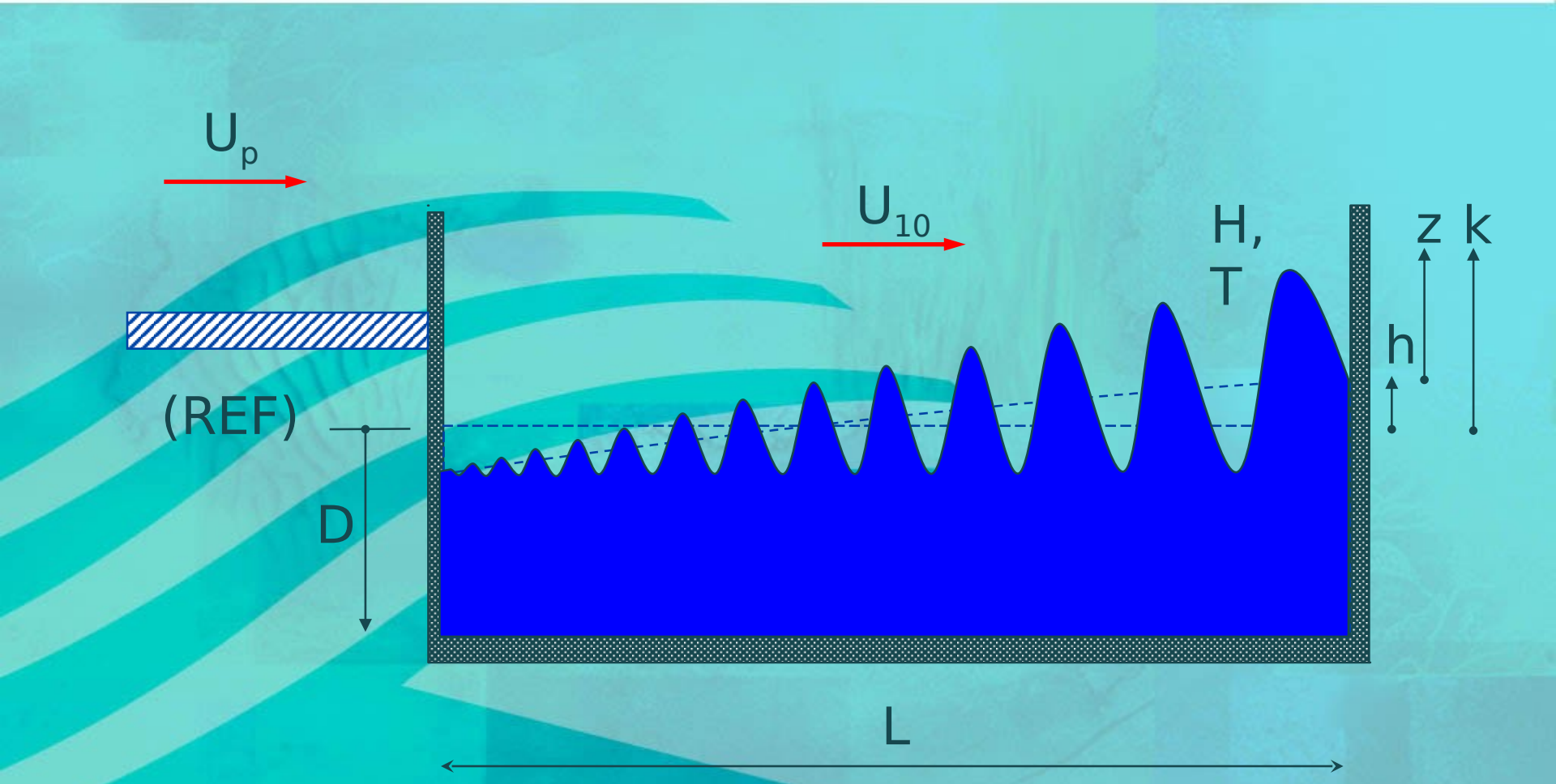
Surge and wave growth combined



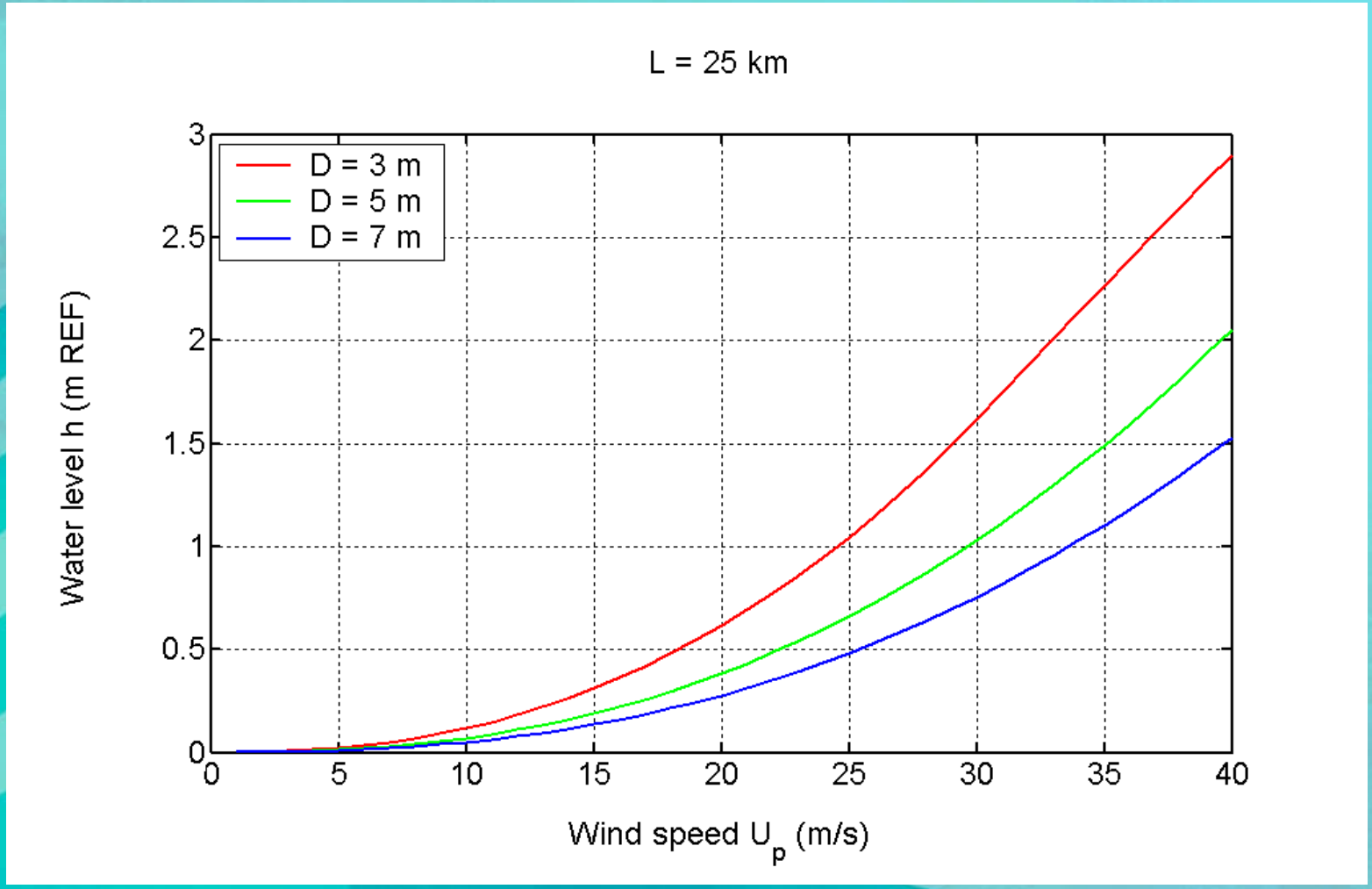
Wave runup



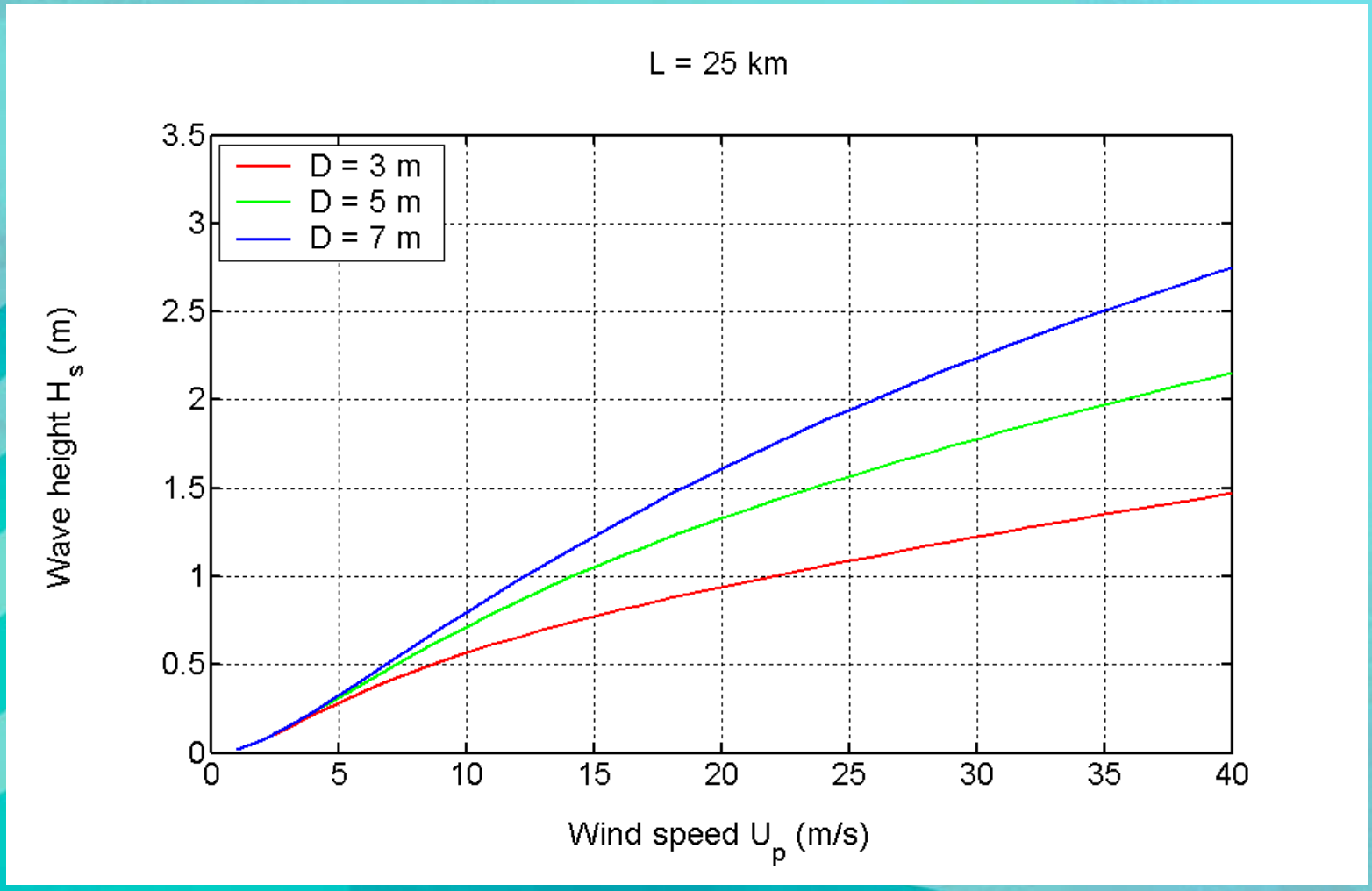
From wind U_p to required crest level k



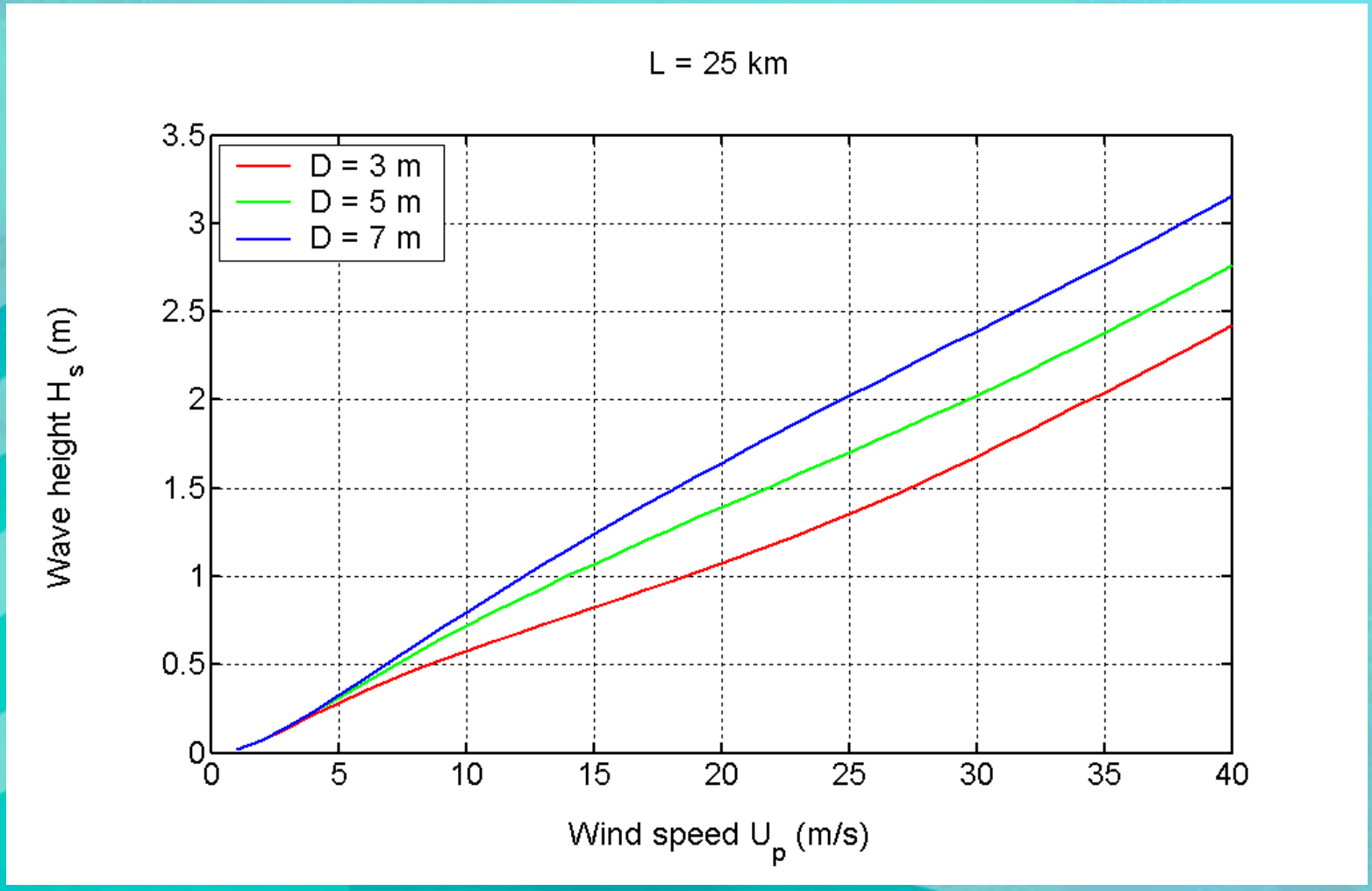
Wind $U_p \rightarrow$ surge h



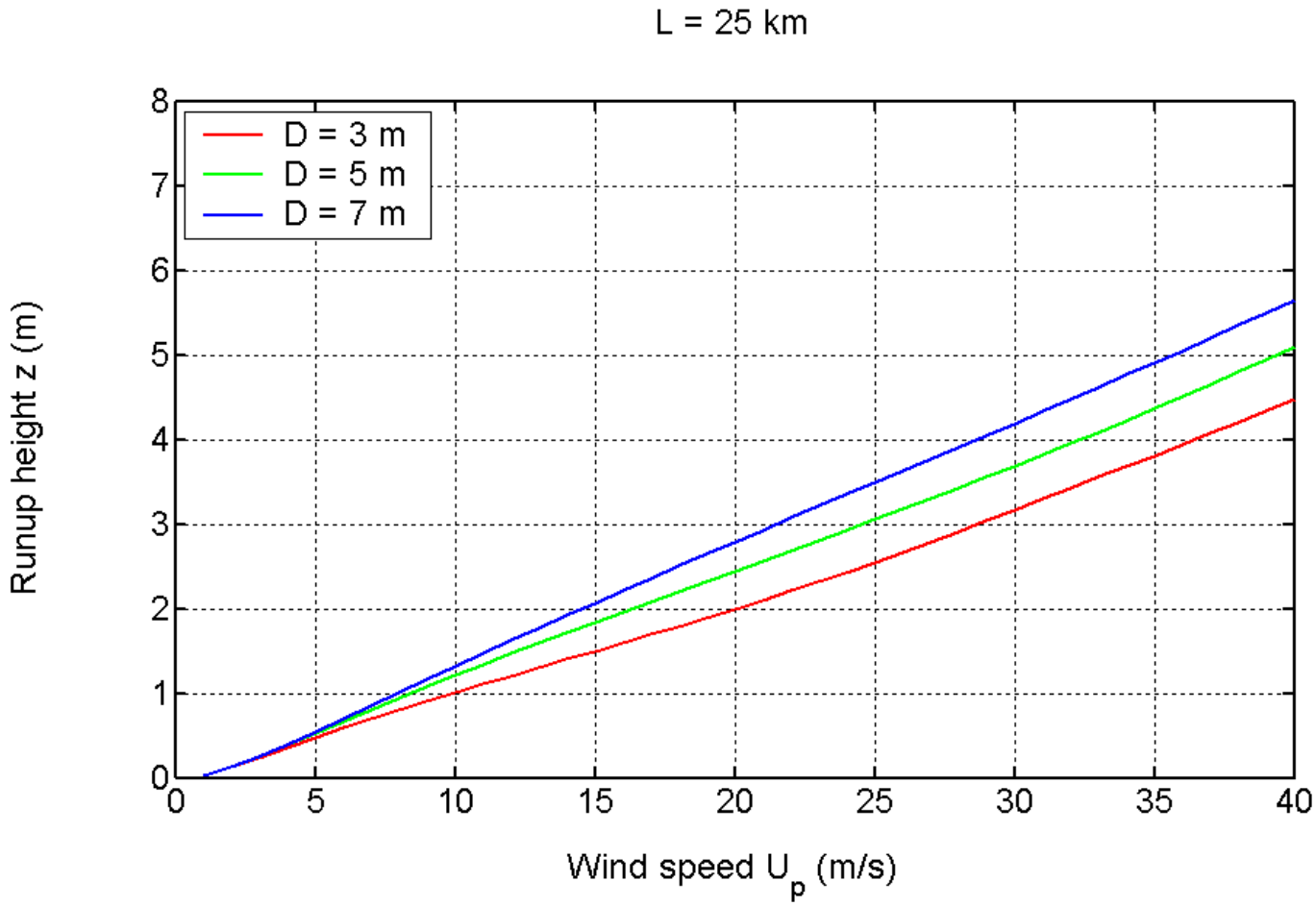
Wind U_p → wave height H_s (excl surge)



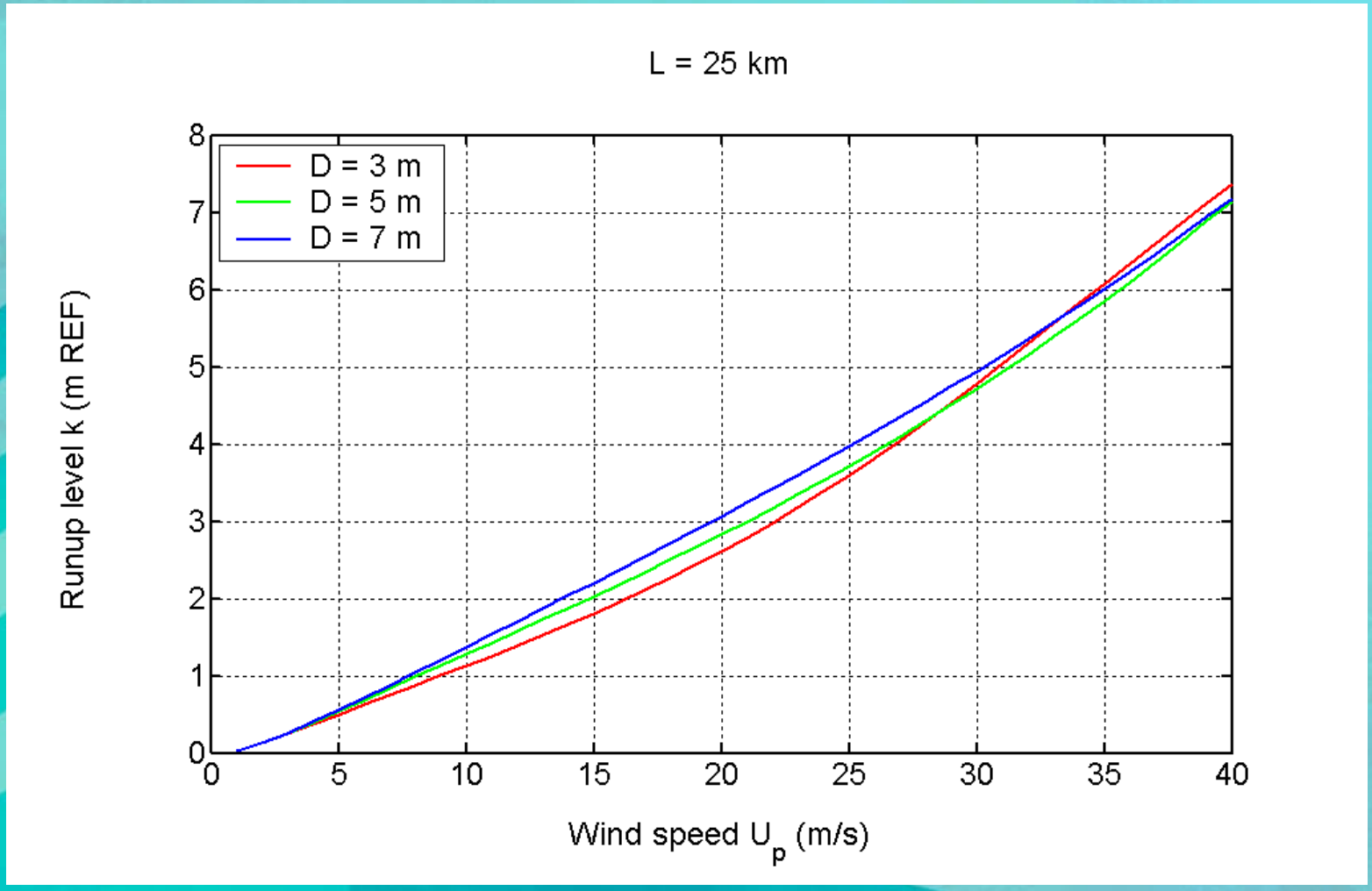
Wind U_p → wave height H_s (incl surge)



Wind U_p → wave runup height z



Wind U_p → required crest level k



Intermediate conclusion

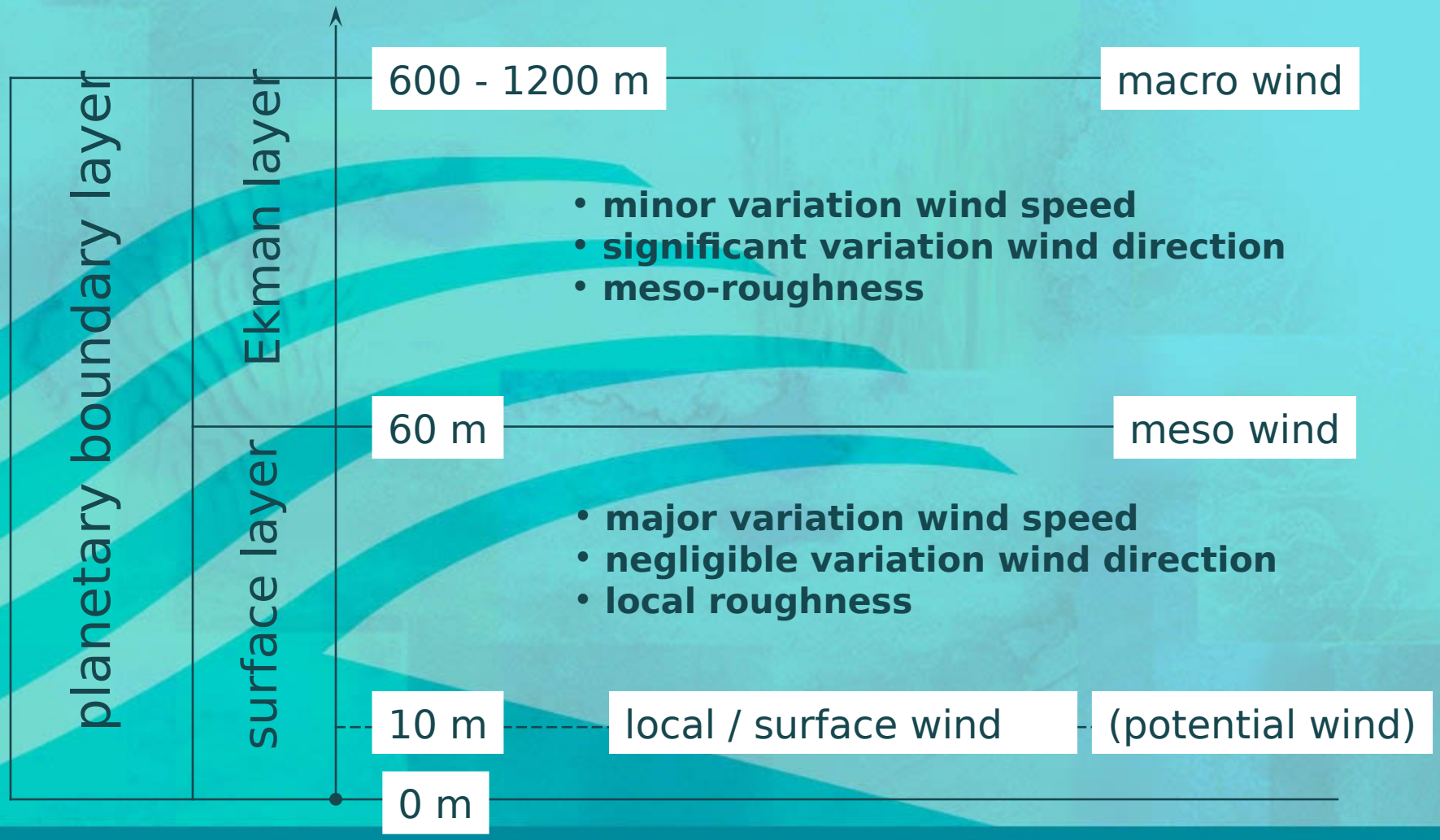
x% uncertainty in wind speed

implies

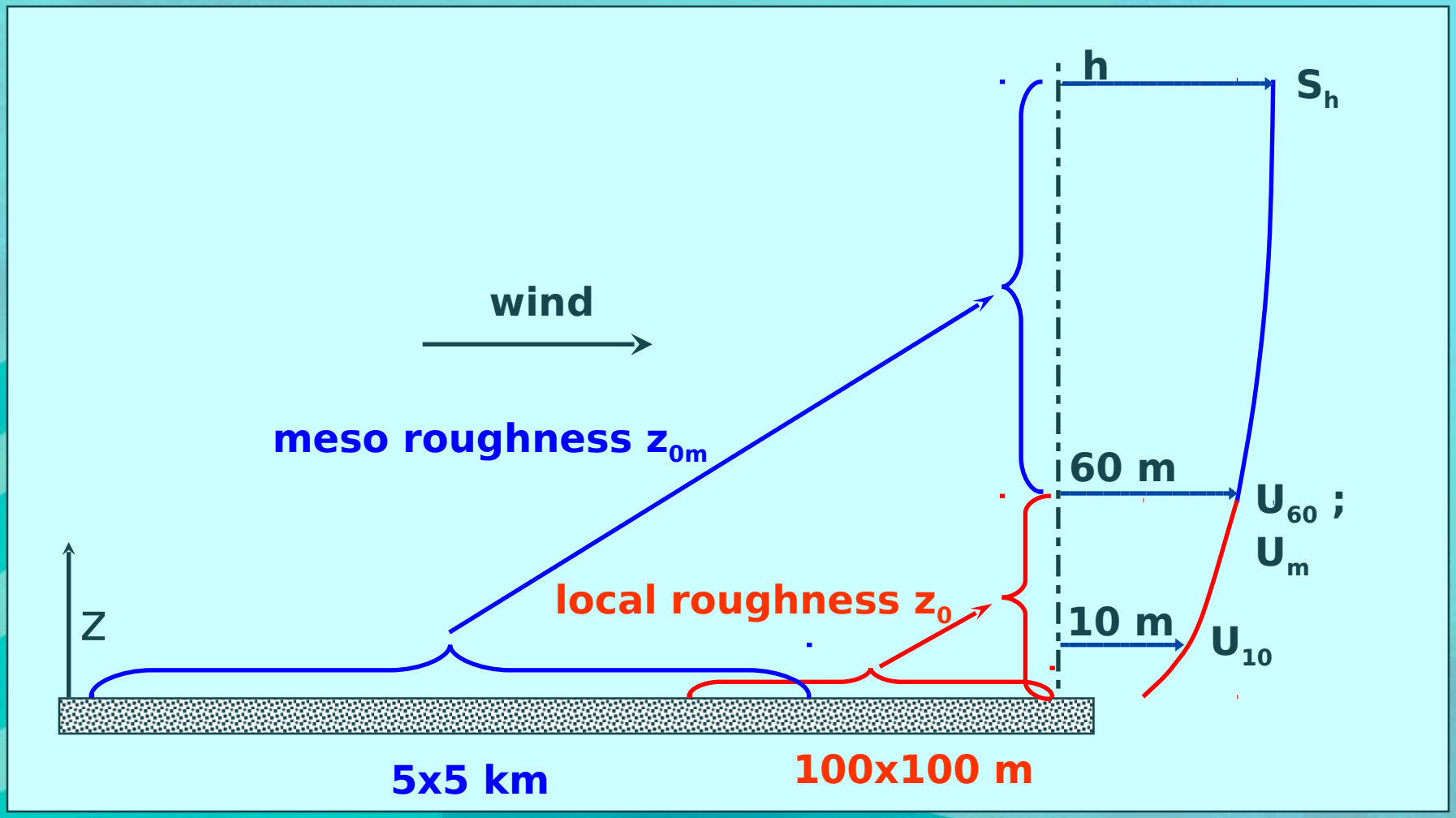
more than x% uncertainty in required crest level

KNMI wind measurement sites

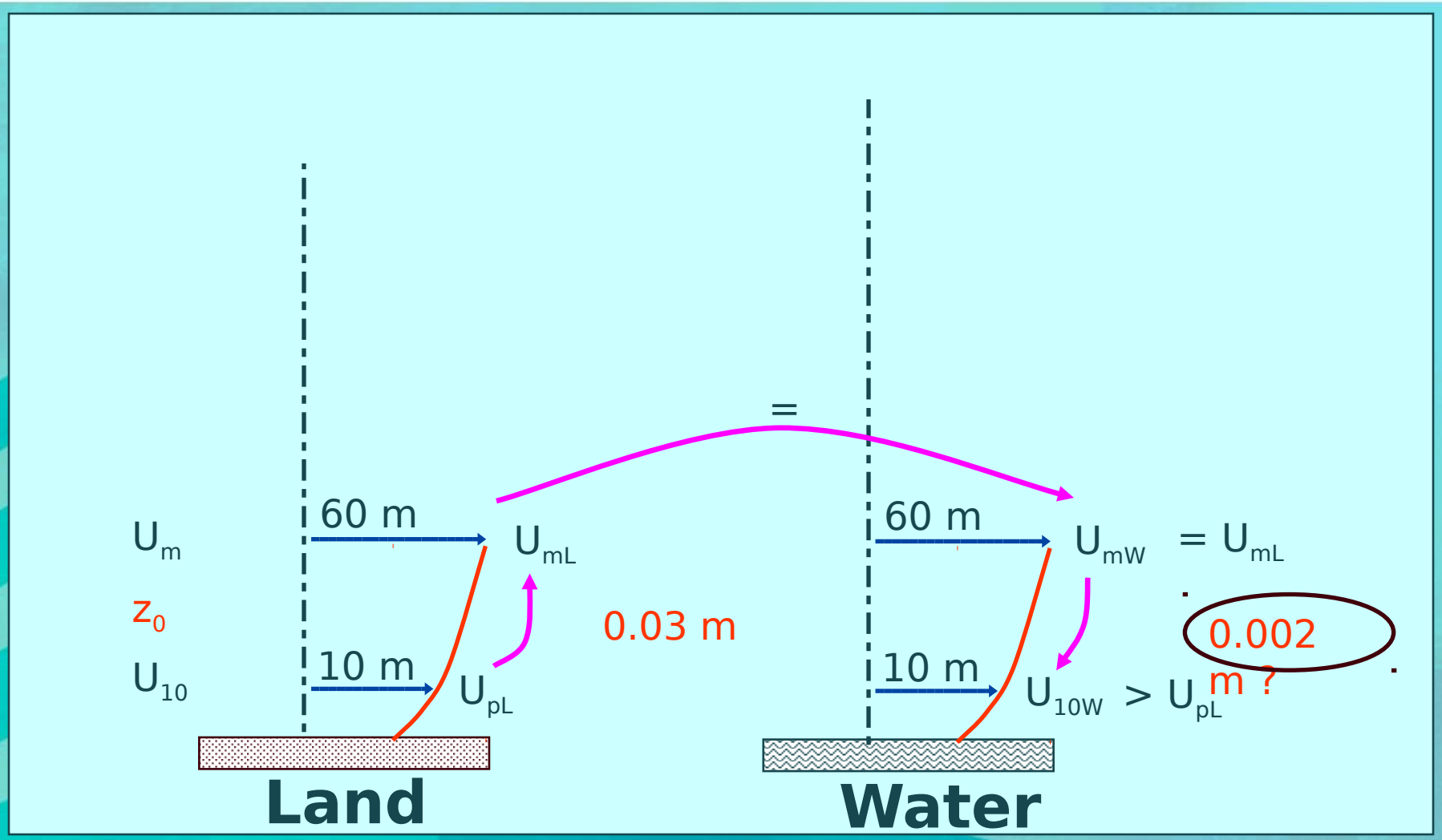
“Two layers” approach (1)



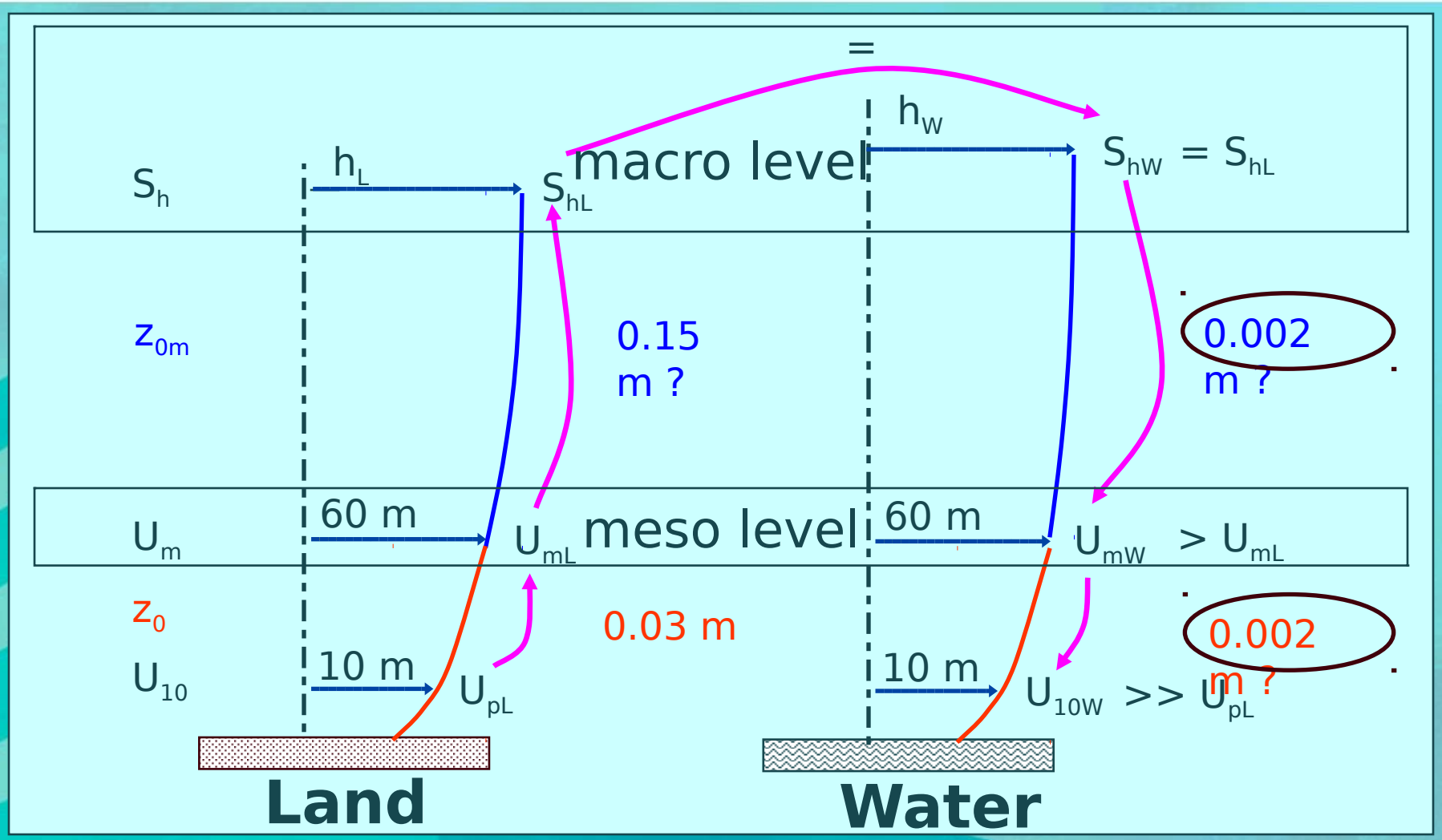
“Two layers” approach (2)



Wind transformation, small distances



Wind transformation, larger distances



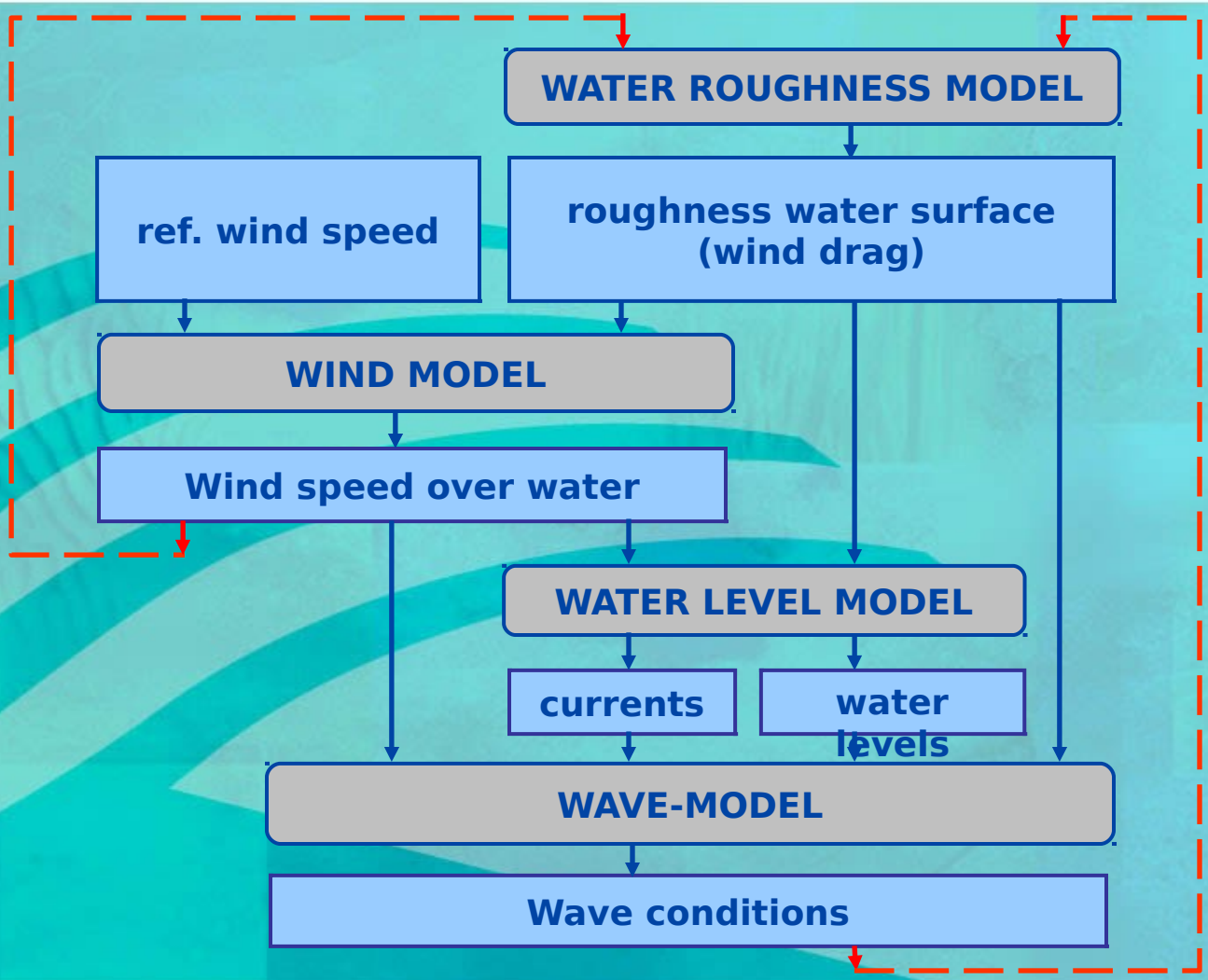
Intermediate conclusion

transformation of wind over land to wind over water

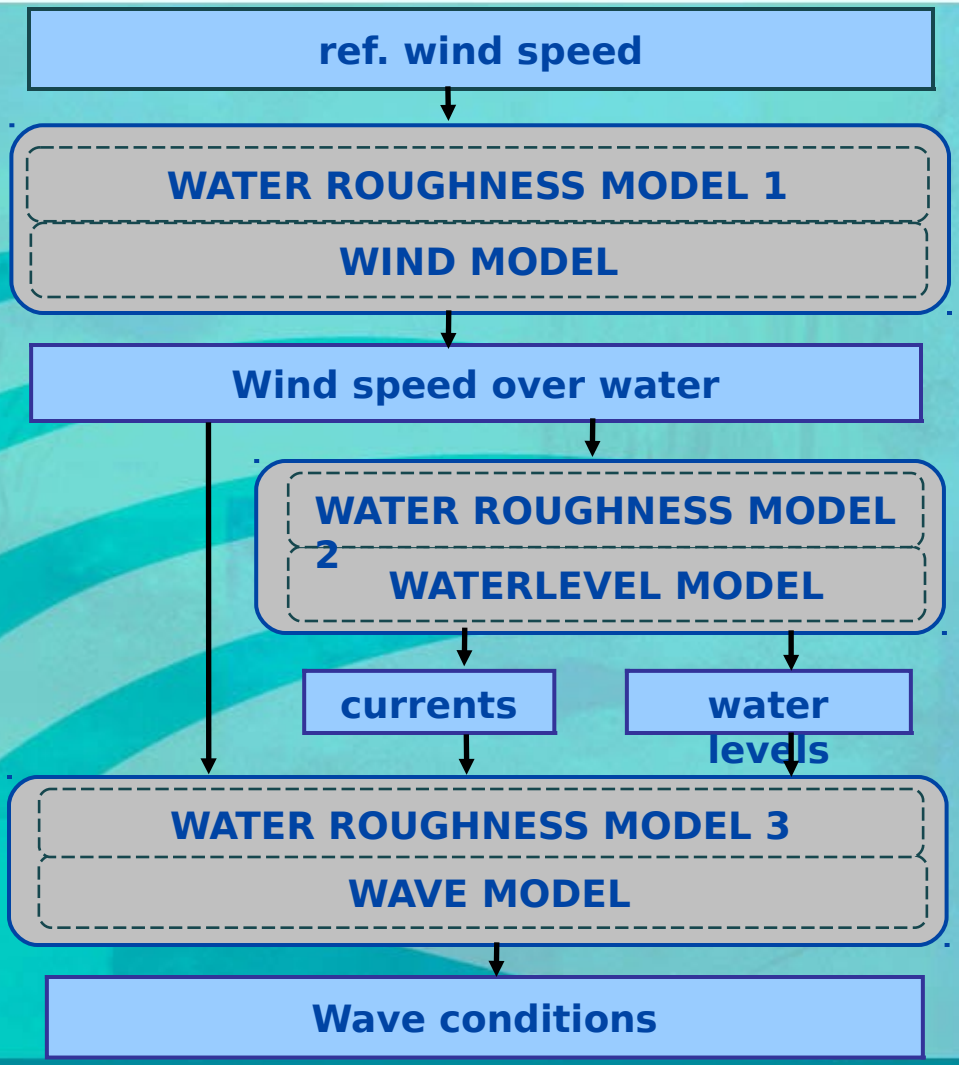
is often required ...

but certainly not straightforward!

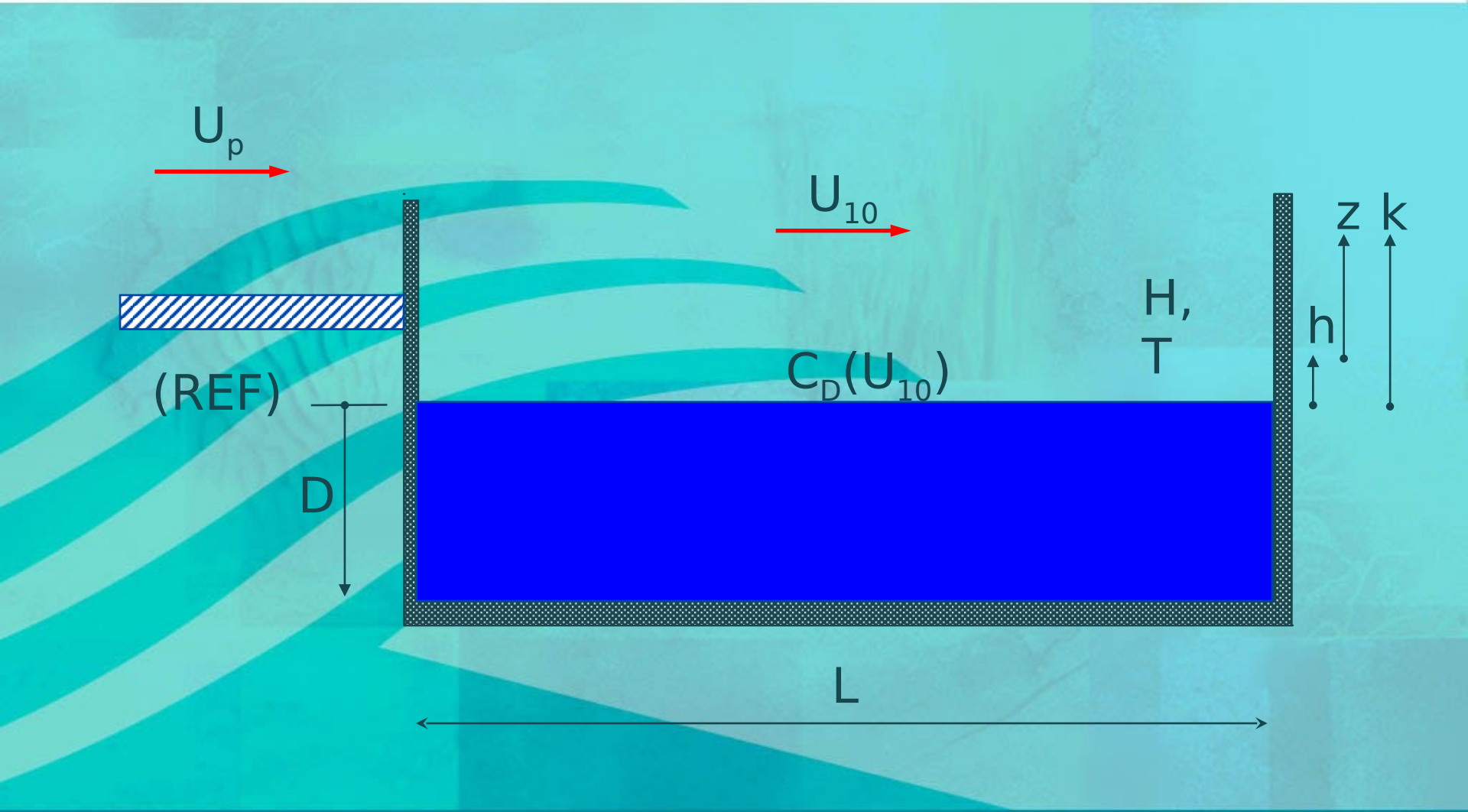
Position wind drag in model chain



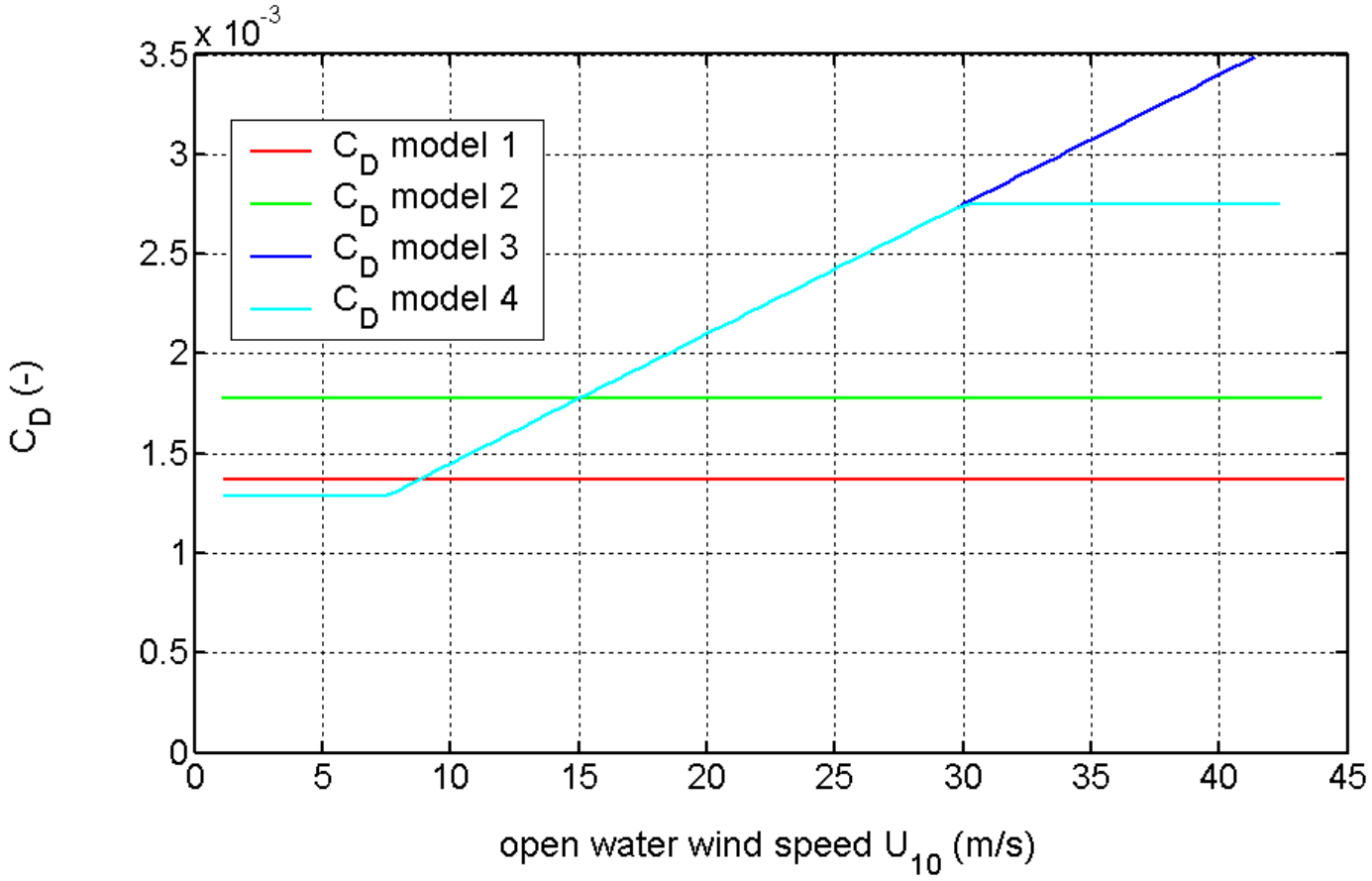
Usual position wind drag



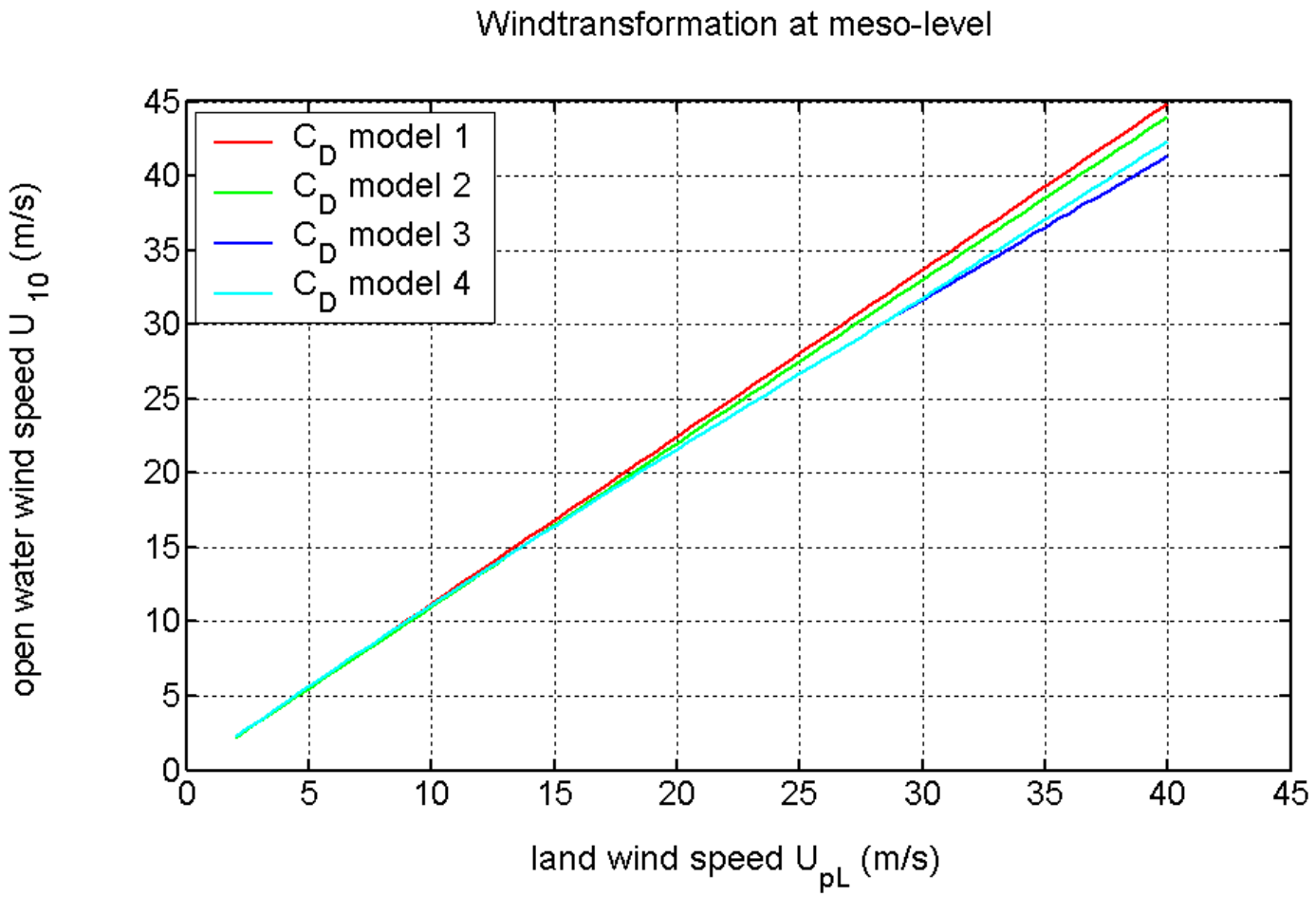
Wind over land and water



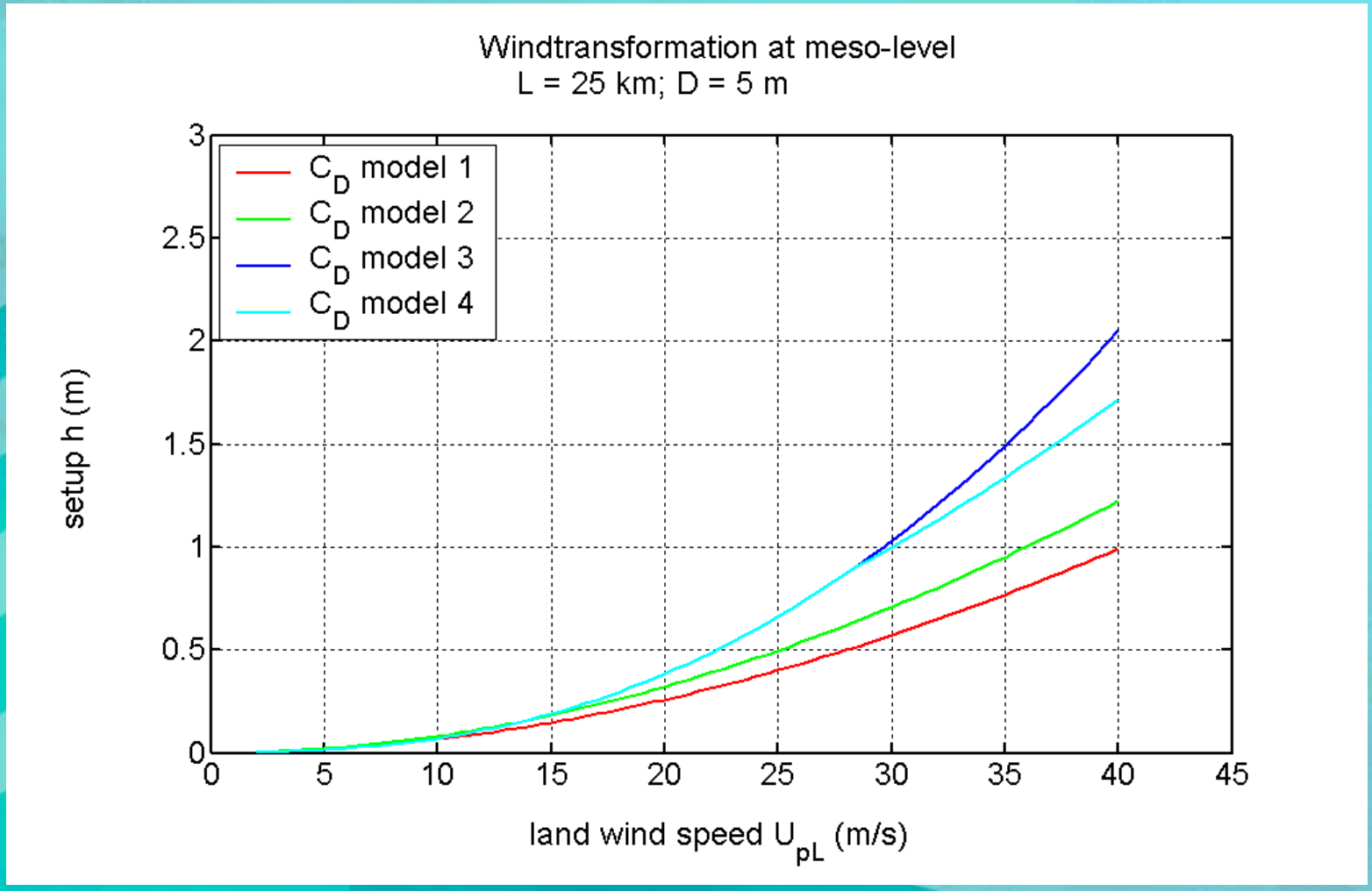
Wind drag relationships



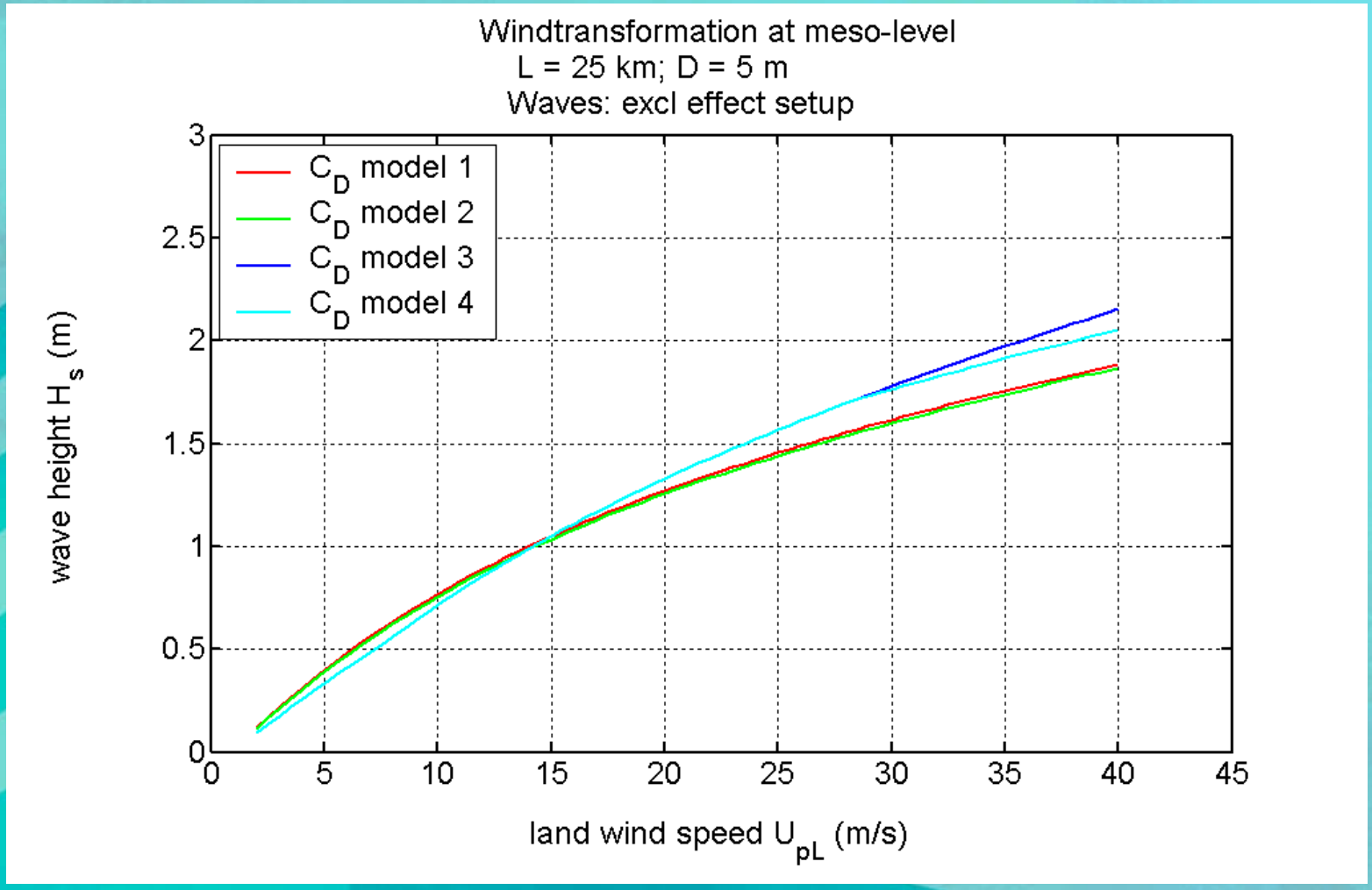
From Wind over land to wind over water



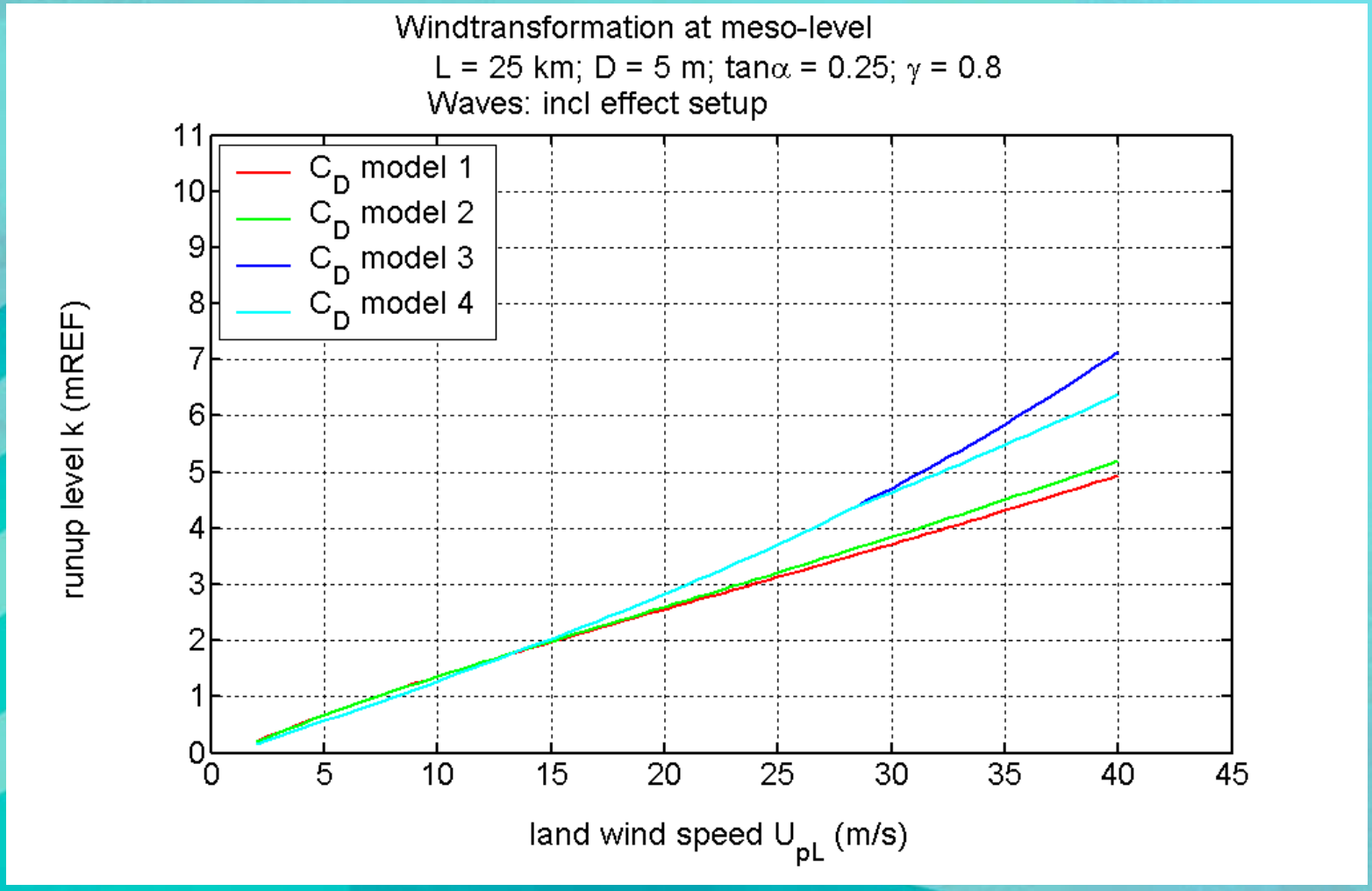
From Wind over land to wind over water



From Wind over land to wind over water



From Wind over land to wind over water



Intermediate conclusion

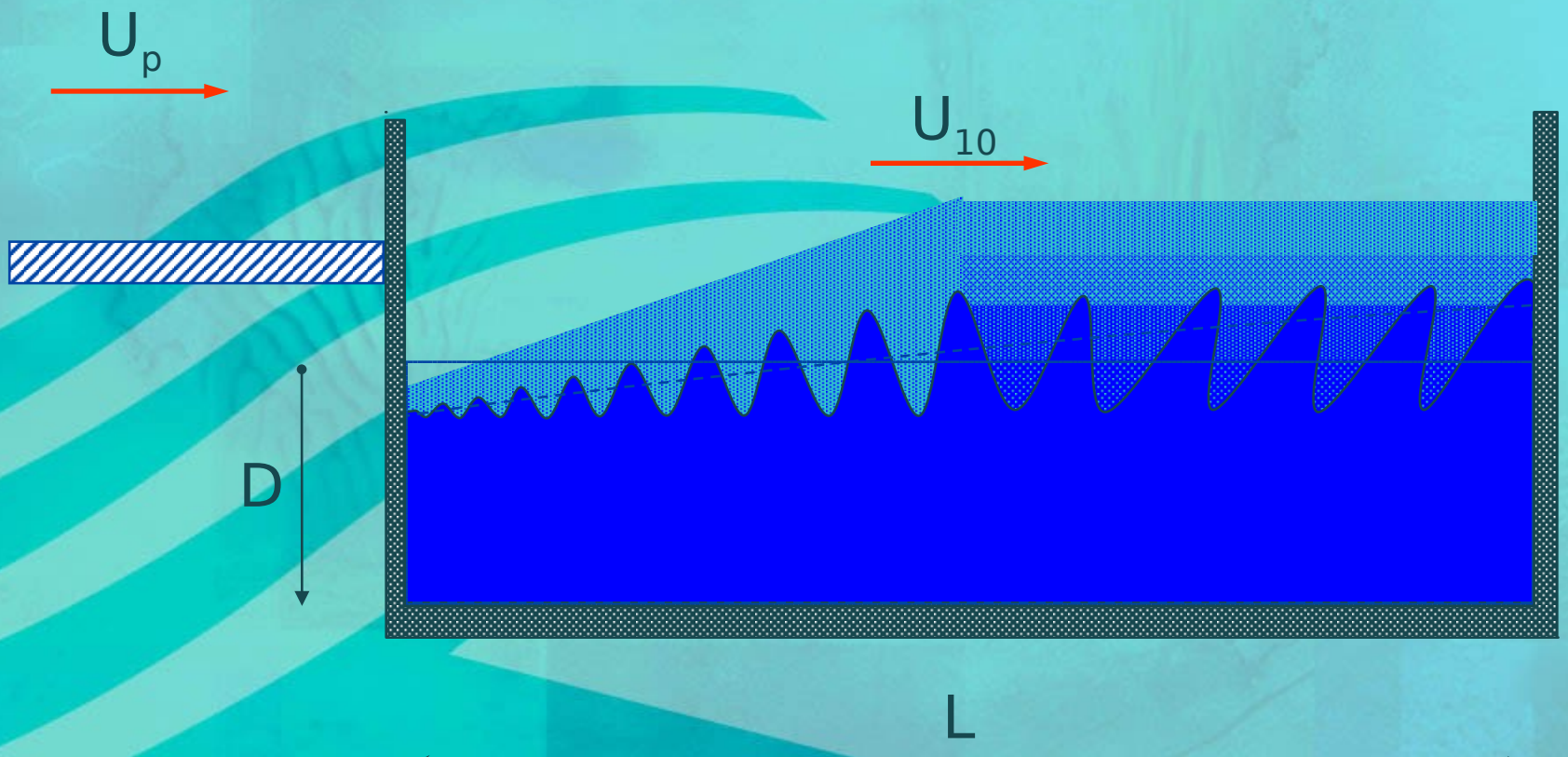
Wind drag is an important parameter

but

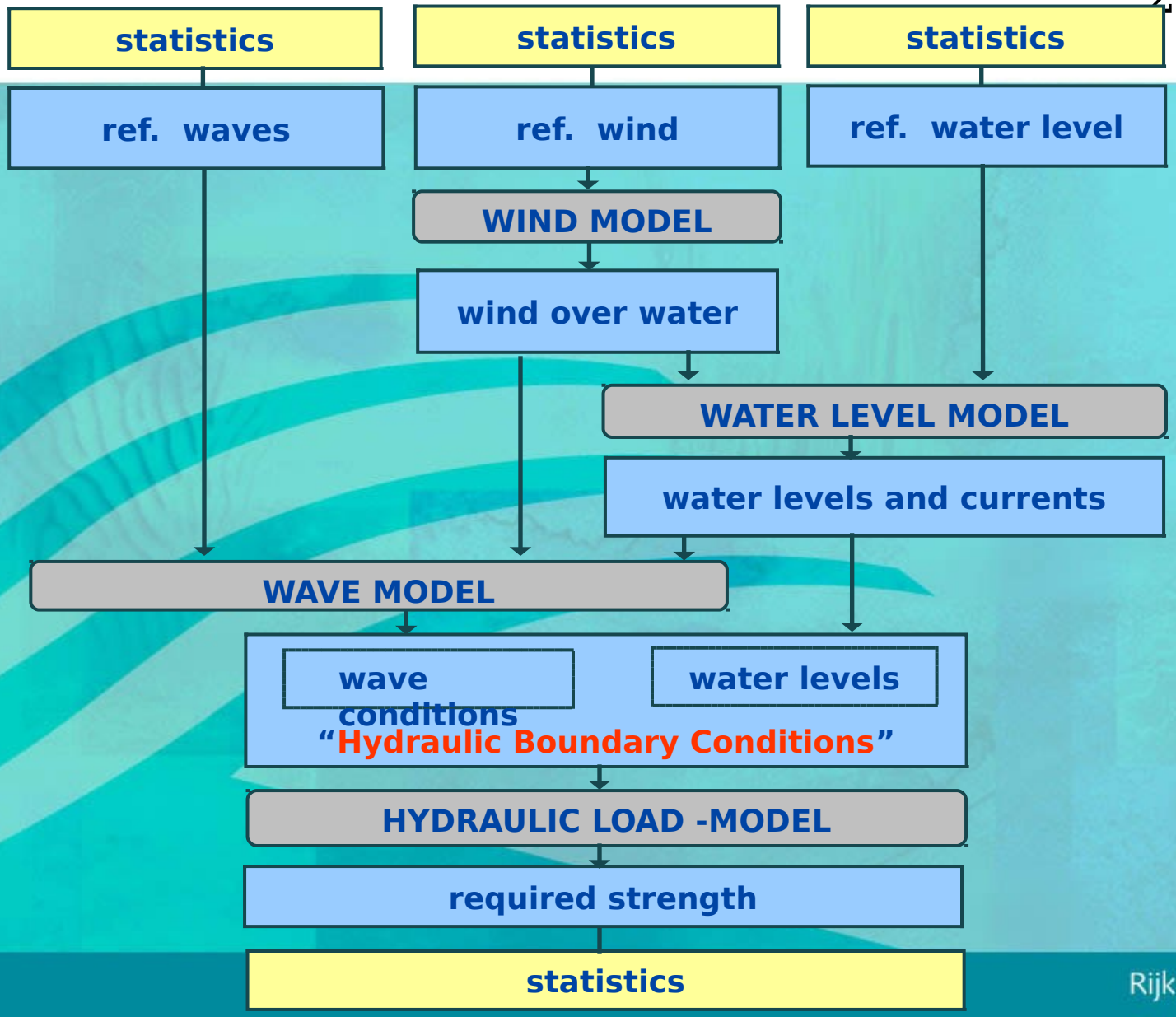
often hidden inside other models, and

hard to calibrate

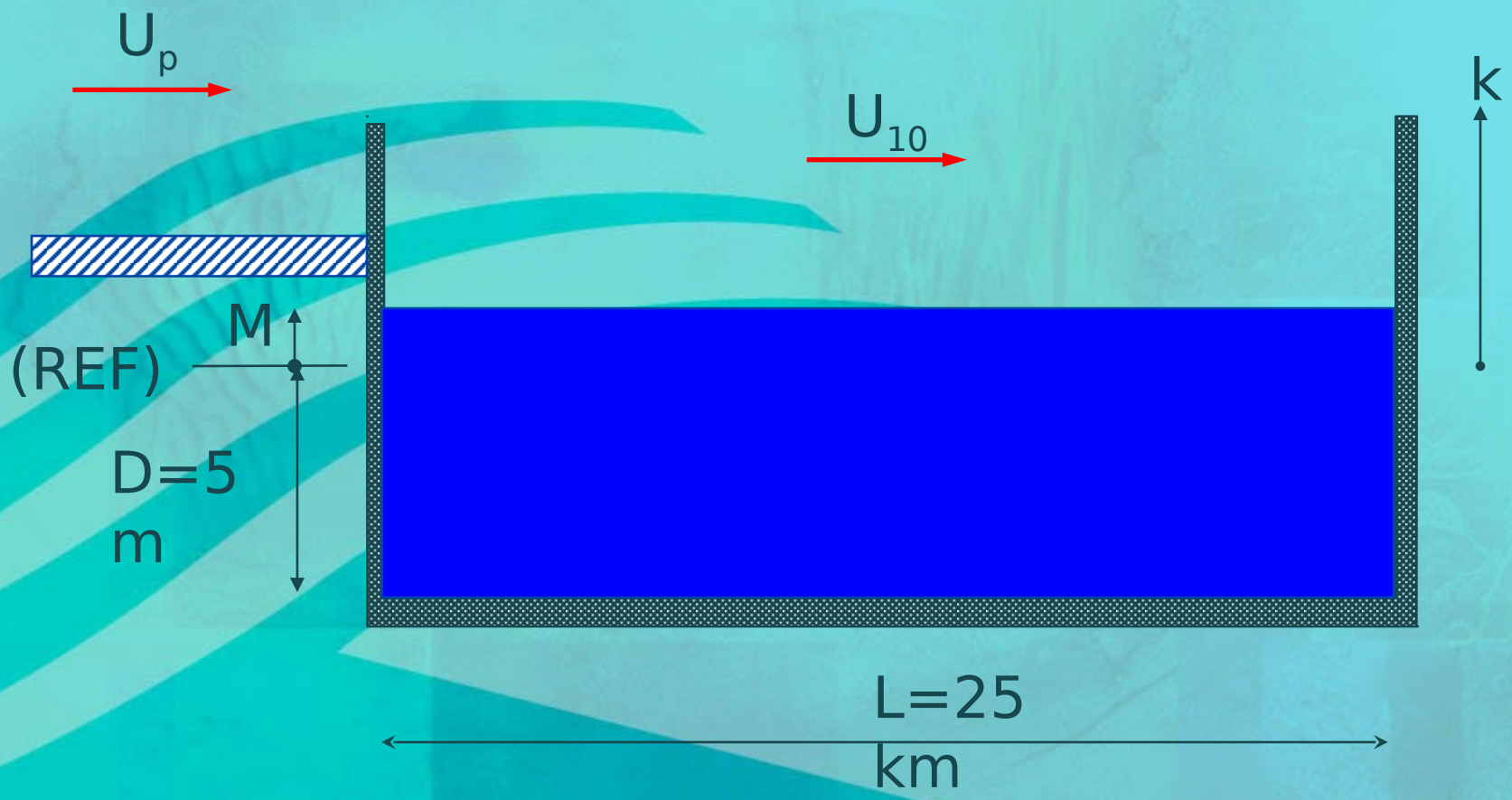
Superstorm: wave breaking and spray



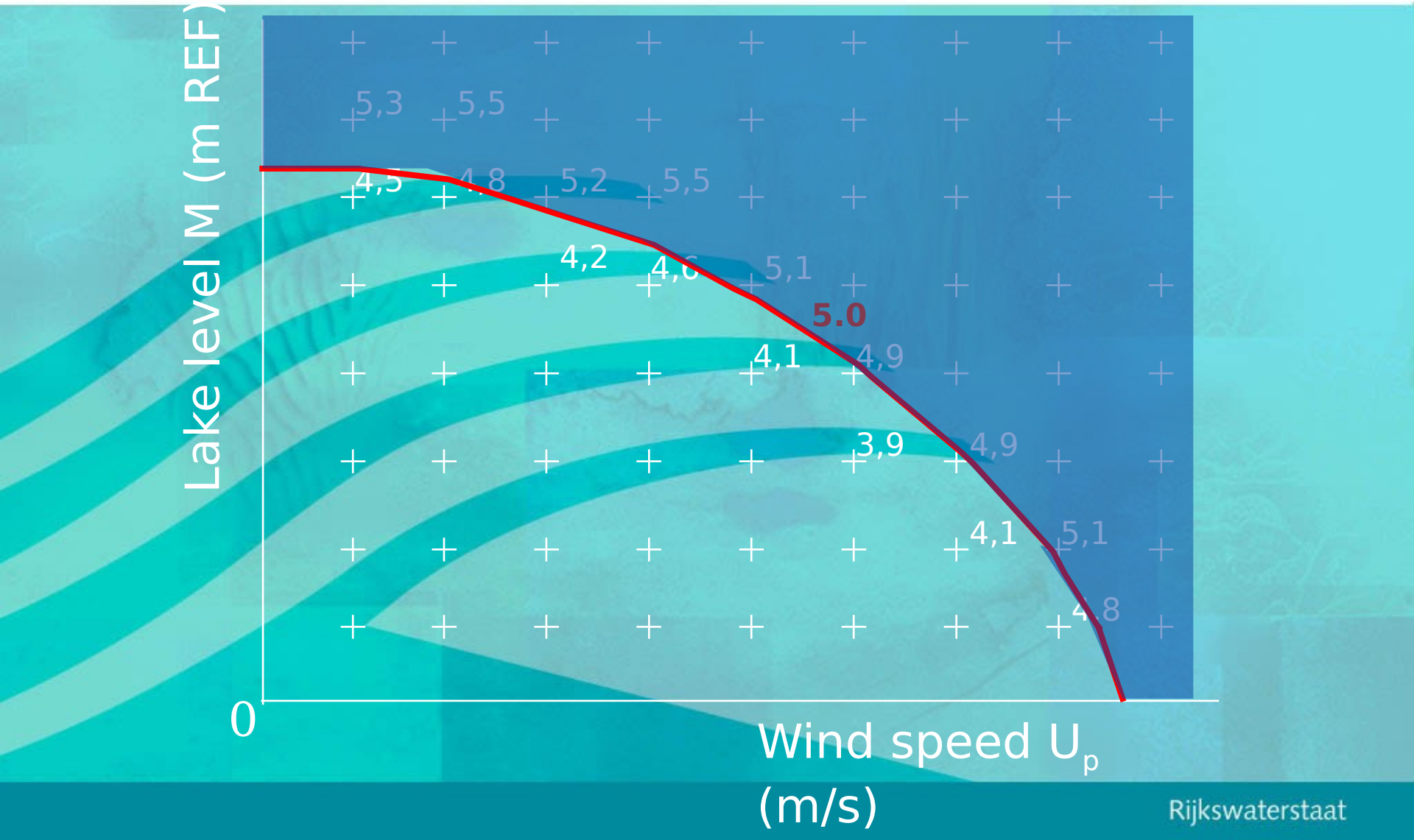
Model chain


statistics
statistics
statistics
ref. waves
ref. wind
ref. water level
WIND MODEL
wind over water
WATER LEVEL MODEL
water levels and currents
WAVE MODEL
wave conditions
water levels
"Hydraulic Boundary Conditions"
HYDRAULIC LOAD -MODEL
required strength
statistics

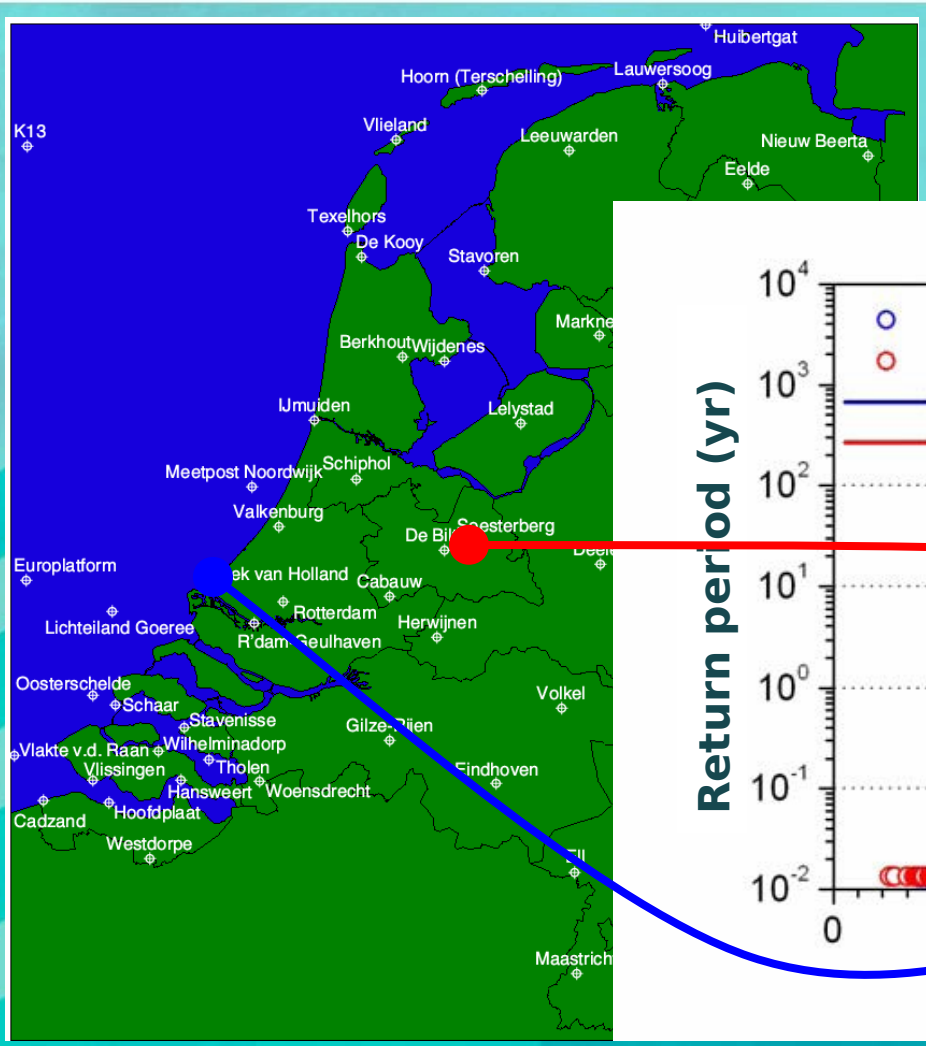
1D: Load depends on Wind and Lake level

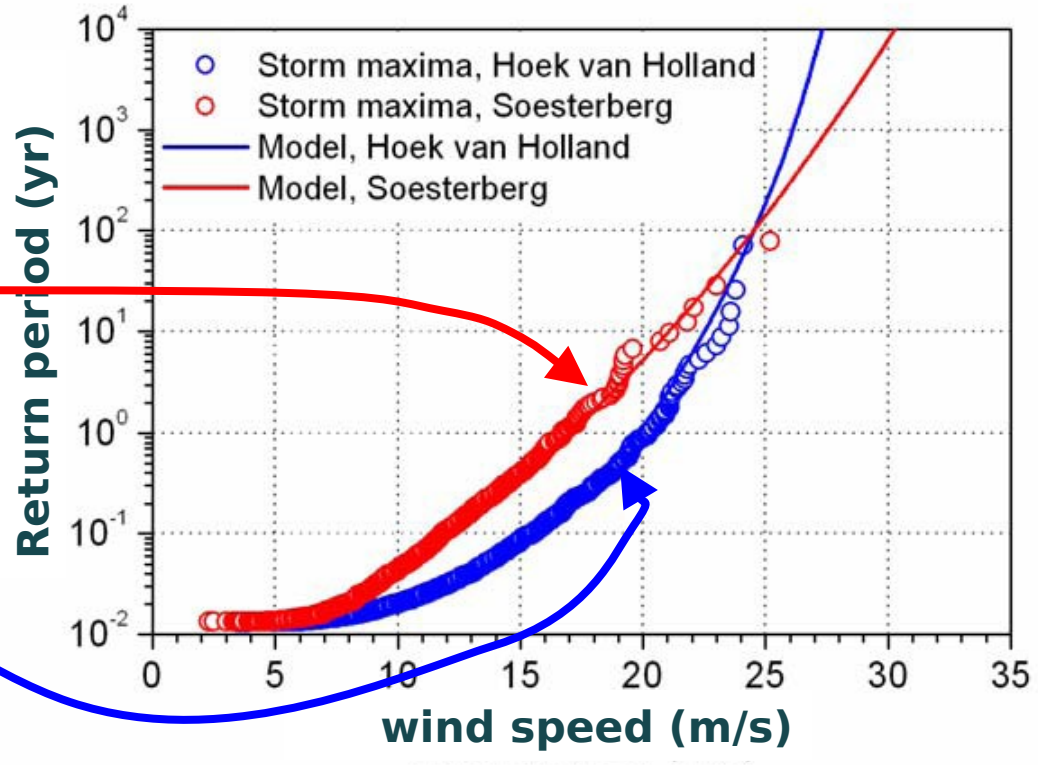


Load k(U_p,M): exceedance probability



Wind statistics depending on location





Intermediate conclusion

Extreme wind statistics

can be applied in an elegant probabilistic design method.

However,

there are major uncertainties in the statistics

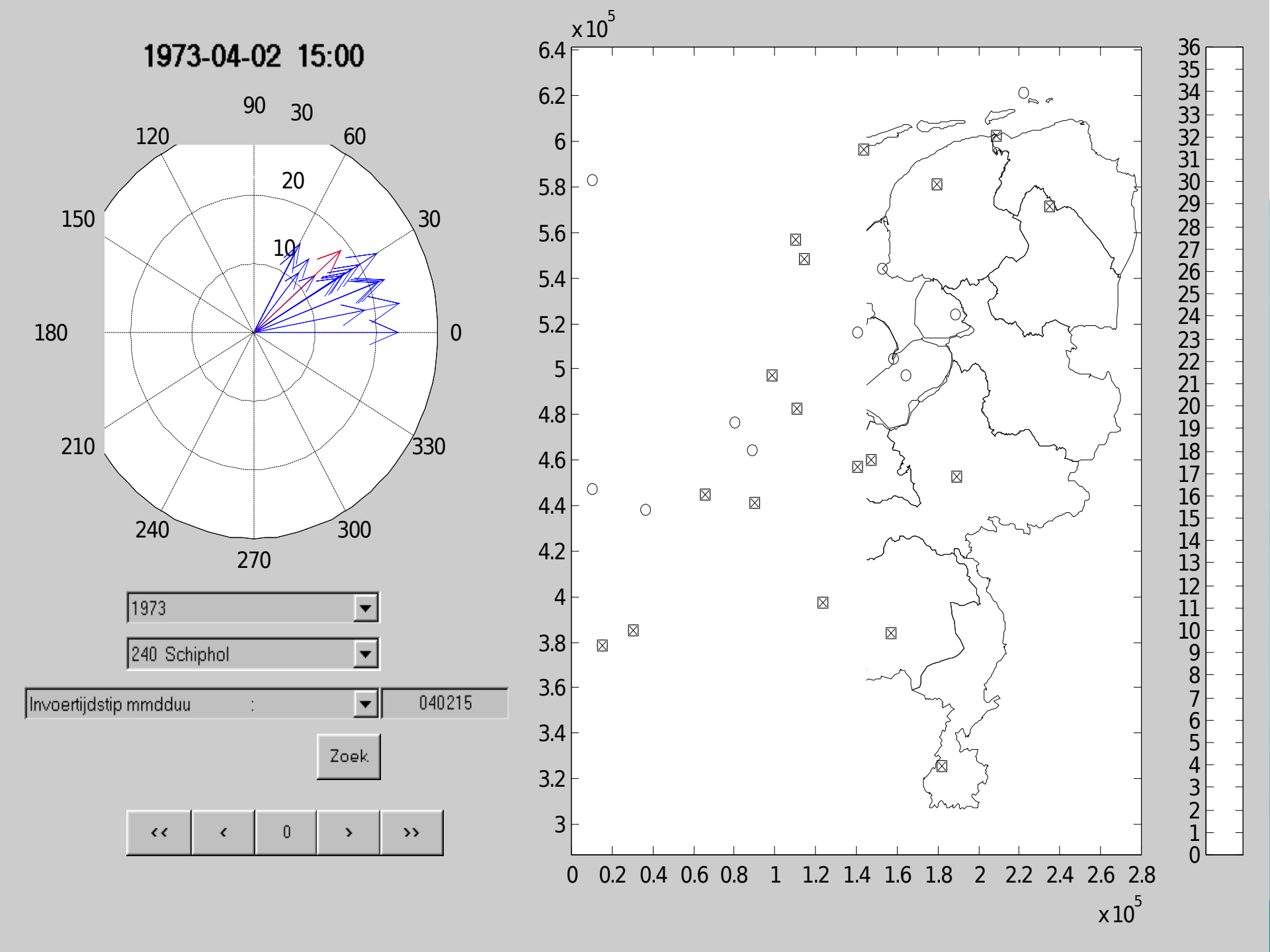
Storm schematization

1. Parameterize $P(U|R_i)$ at measurement locations
2. Find $P(U|R_i)$ at rectangular grid points around the area of interest

3. Assume spatially uniform direction R_i
4. Find U at grid points for specific P and R_i at grid points

5. Compose simple time series of U (and R)

But … example of reality: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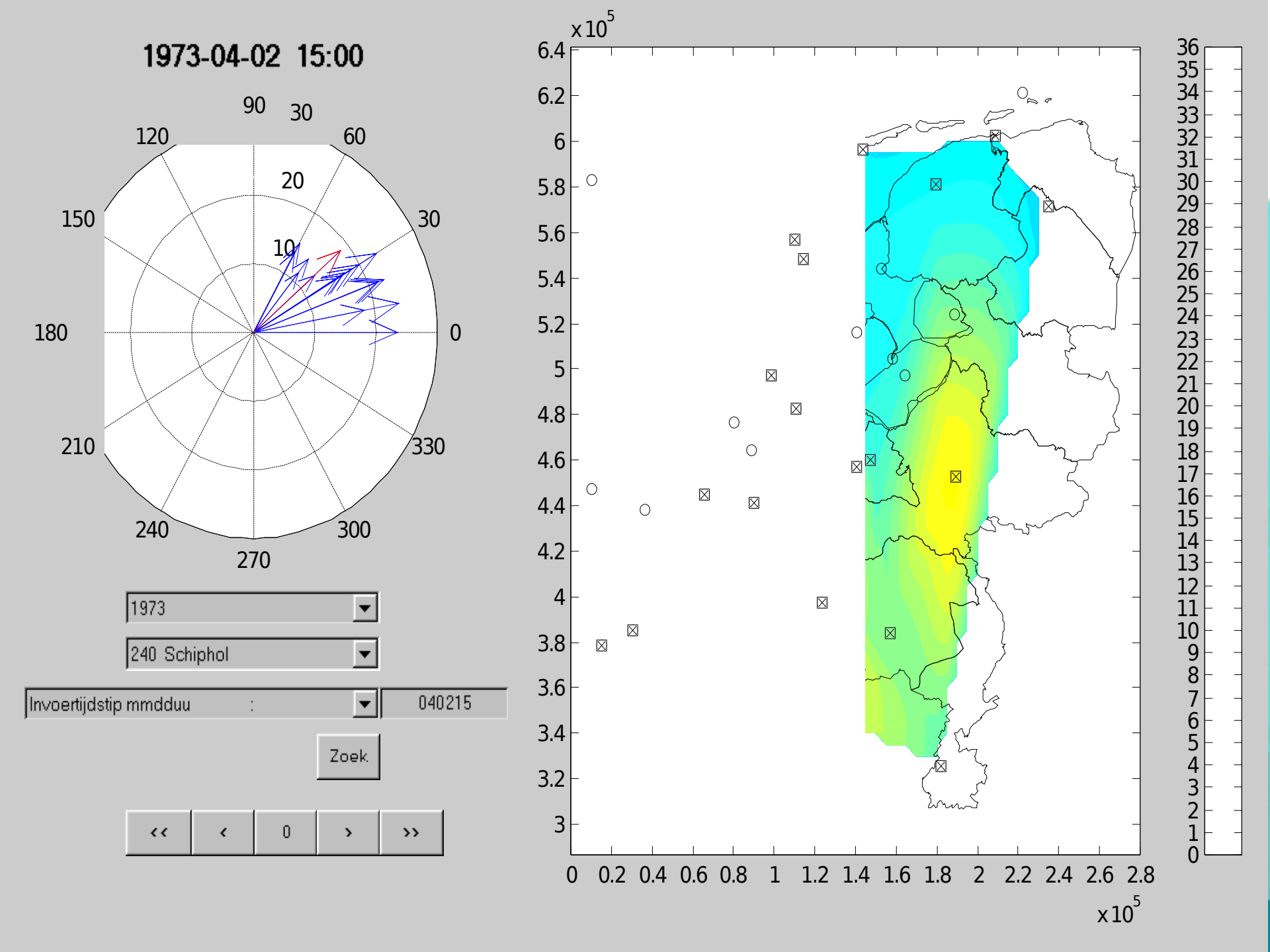
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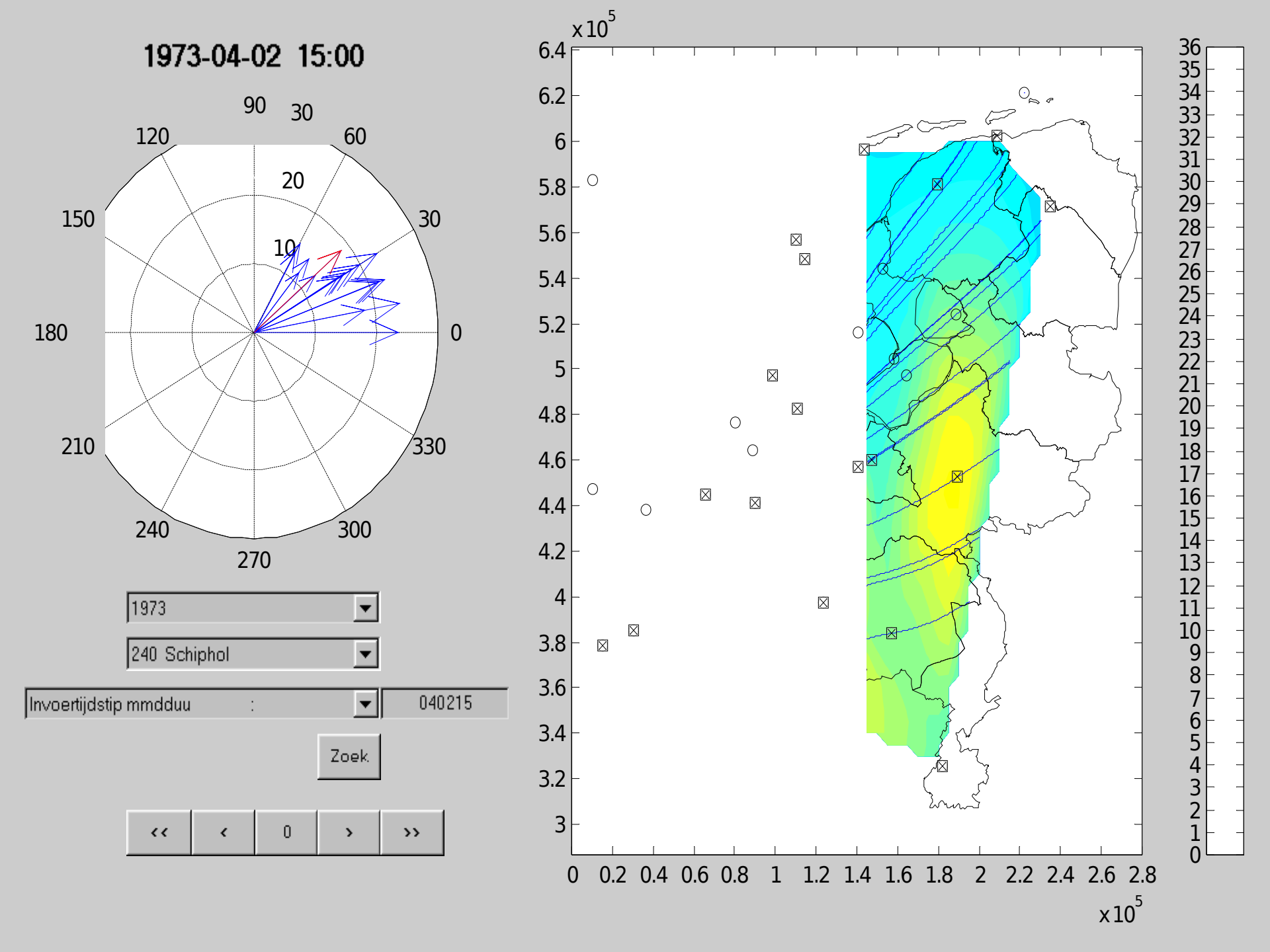
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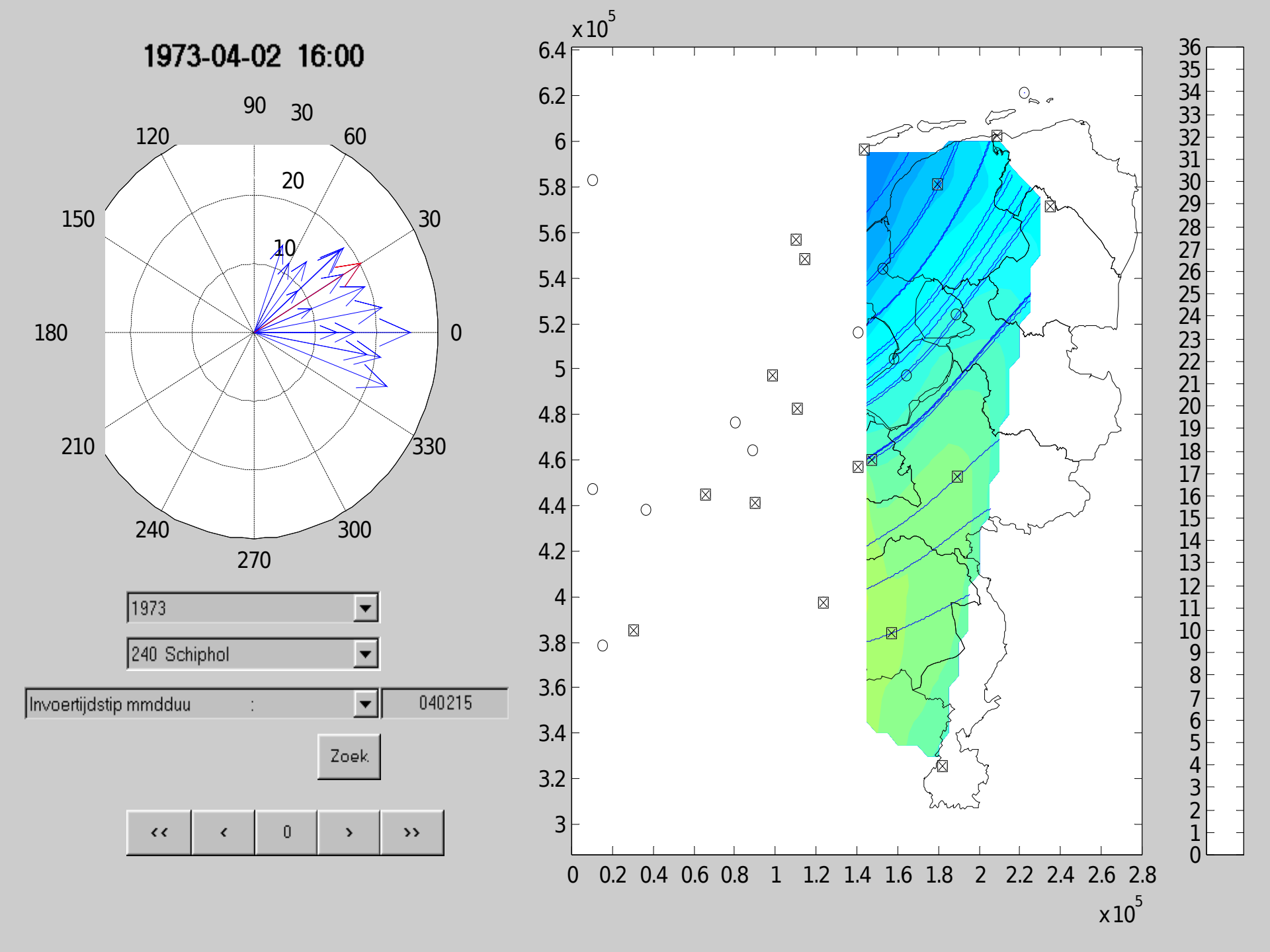
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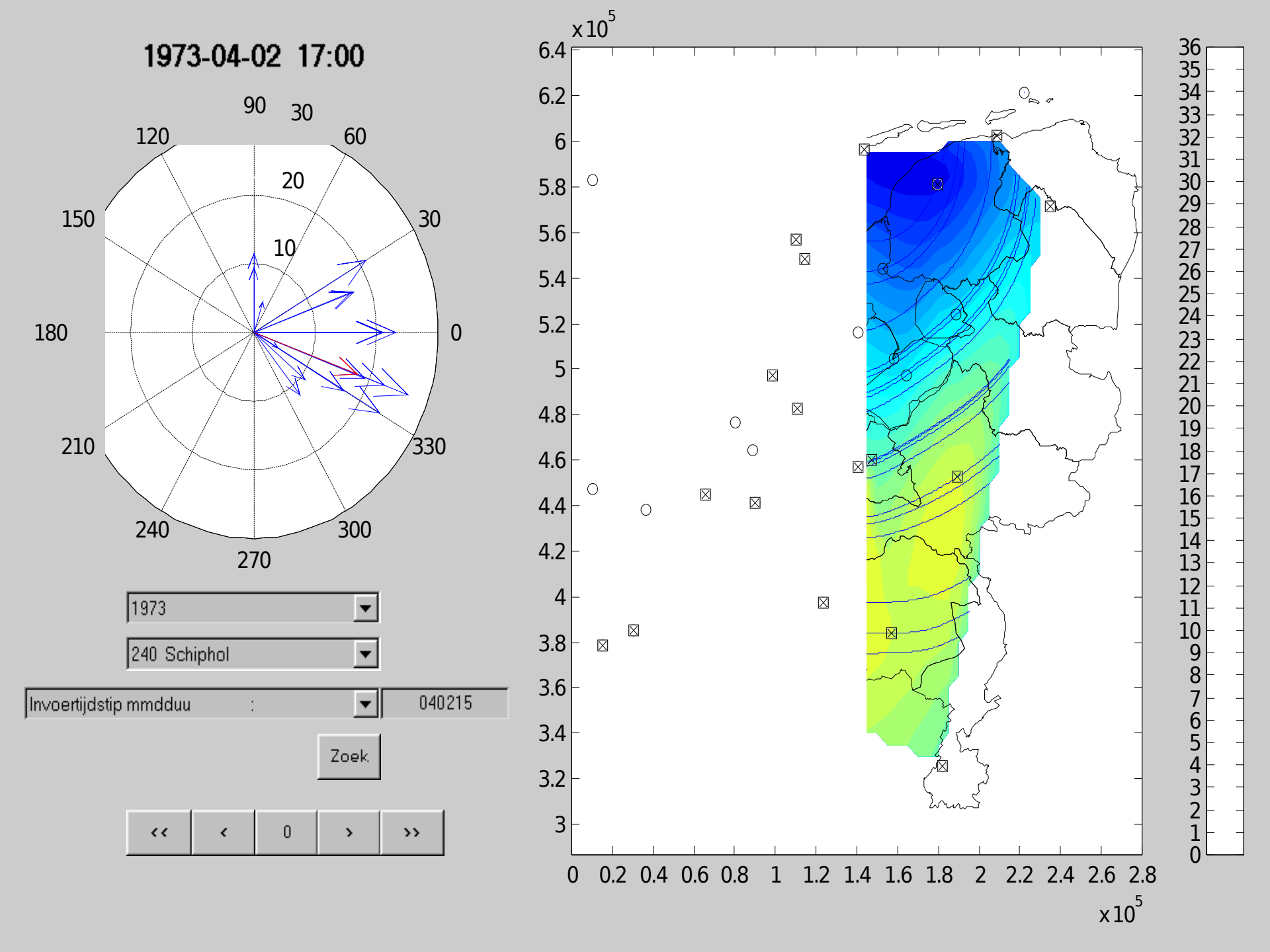
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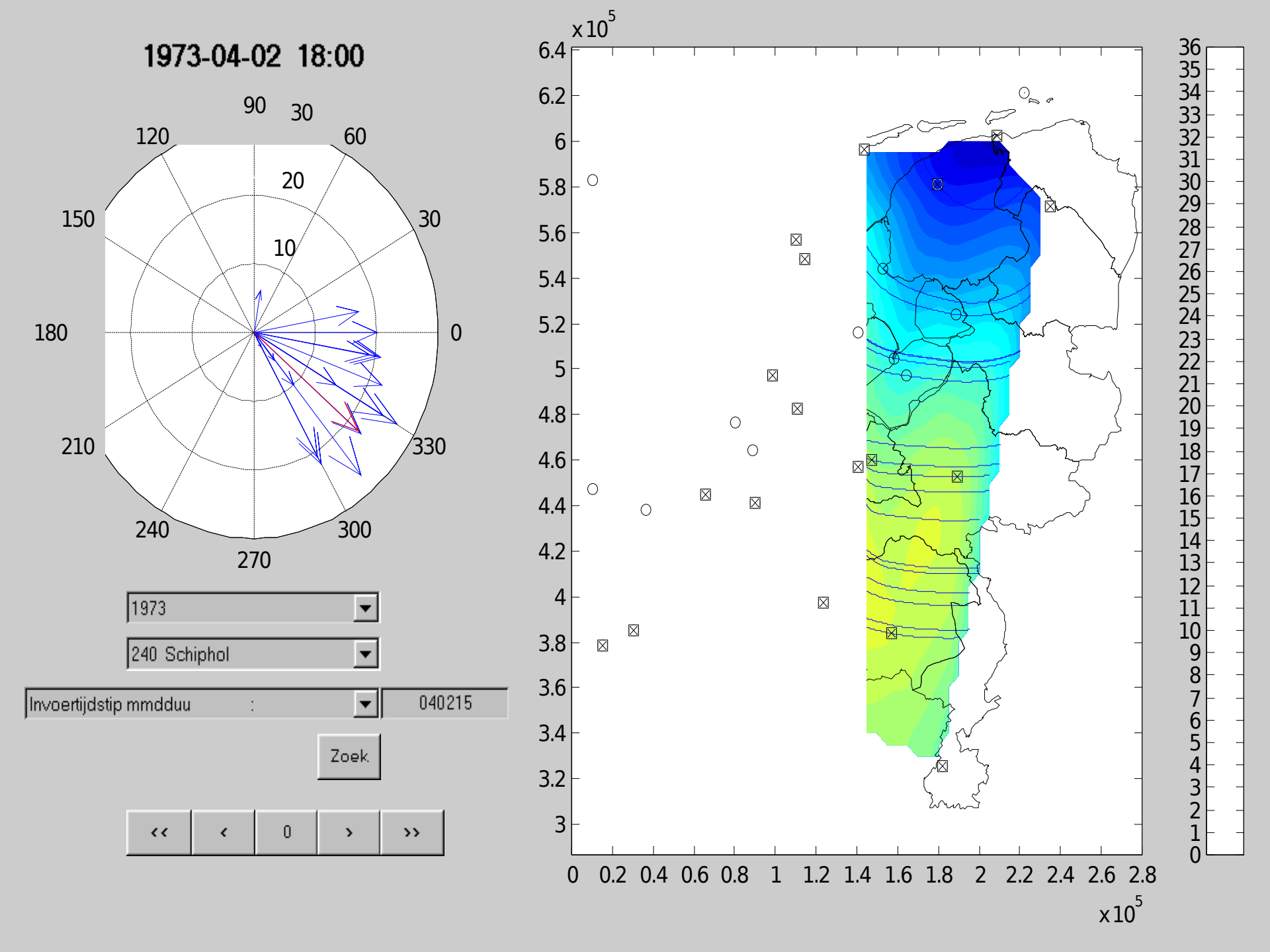
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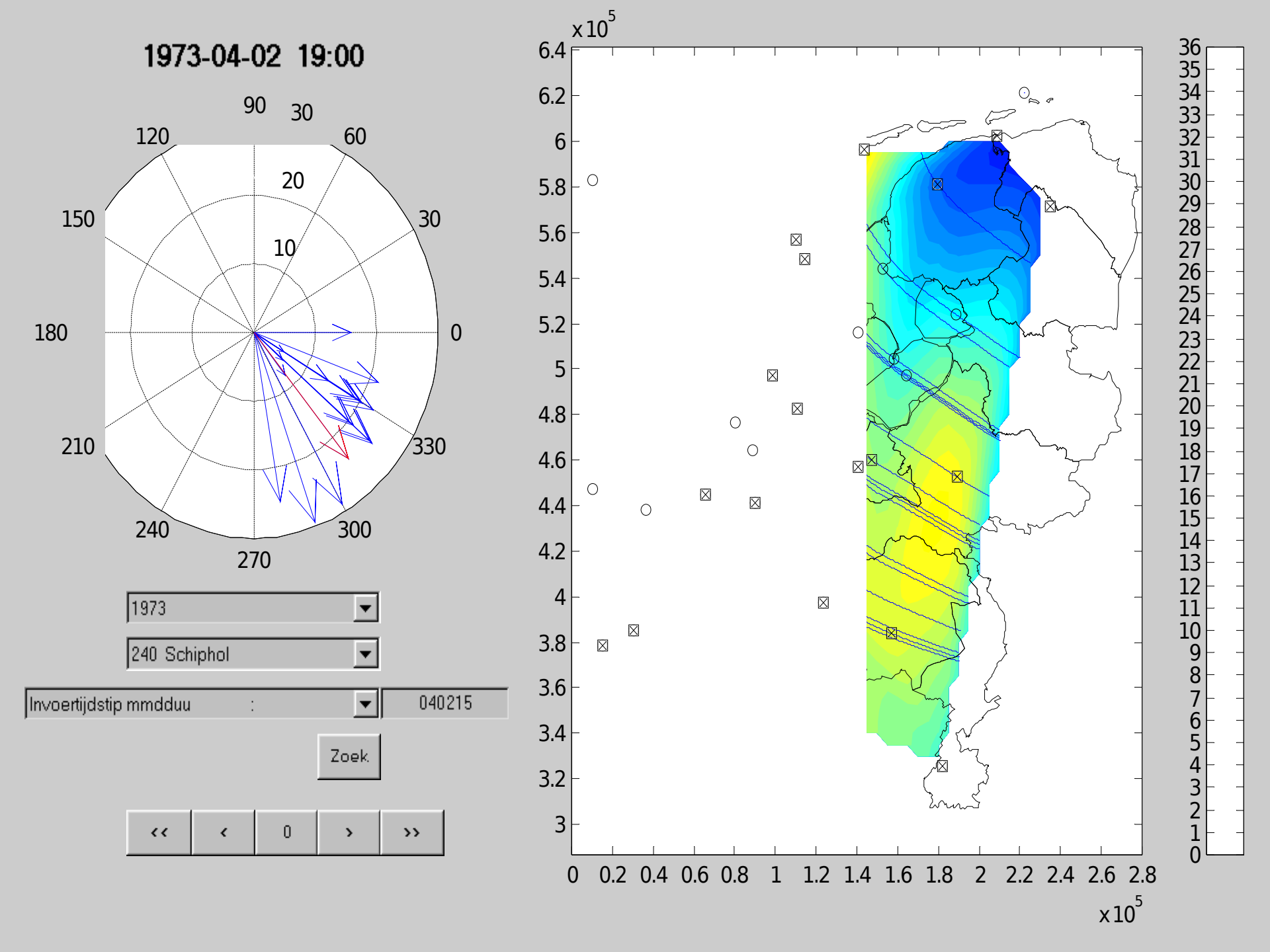
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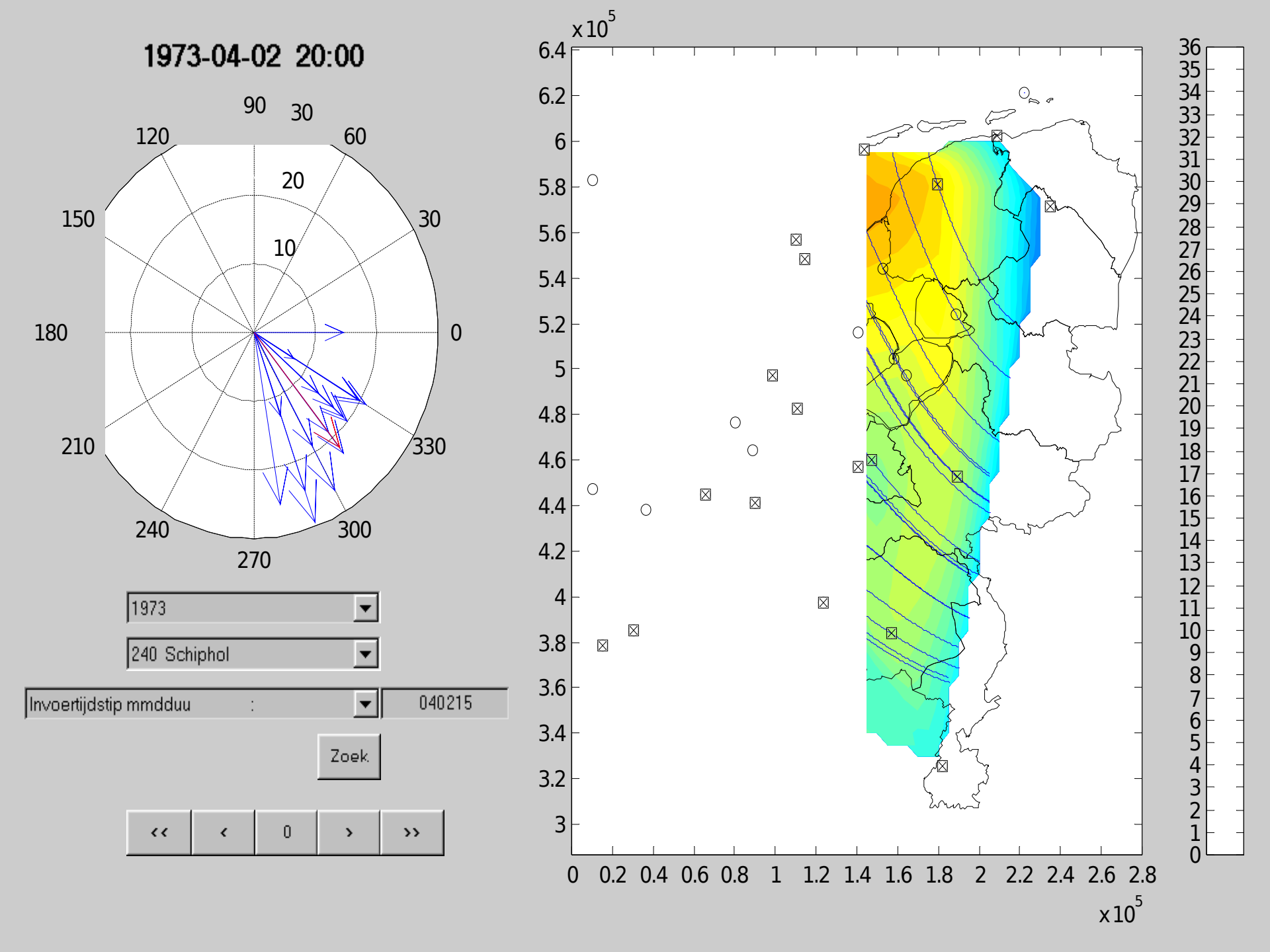
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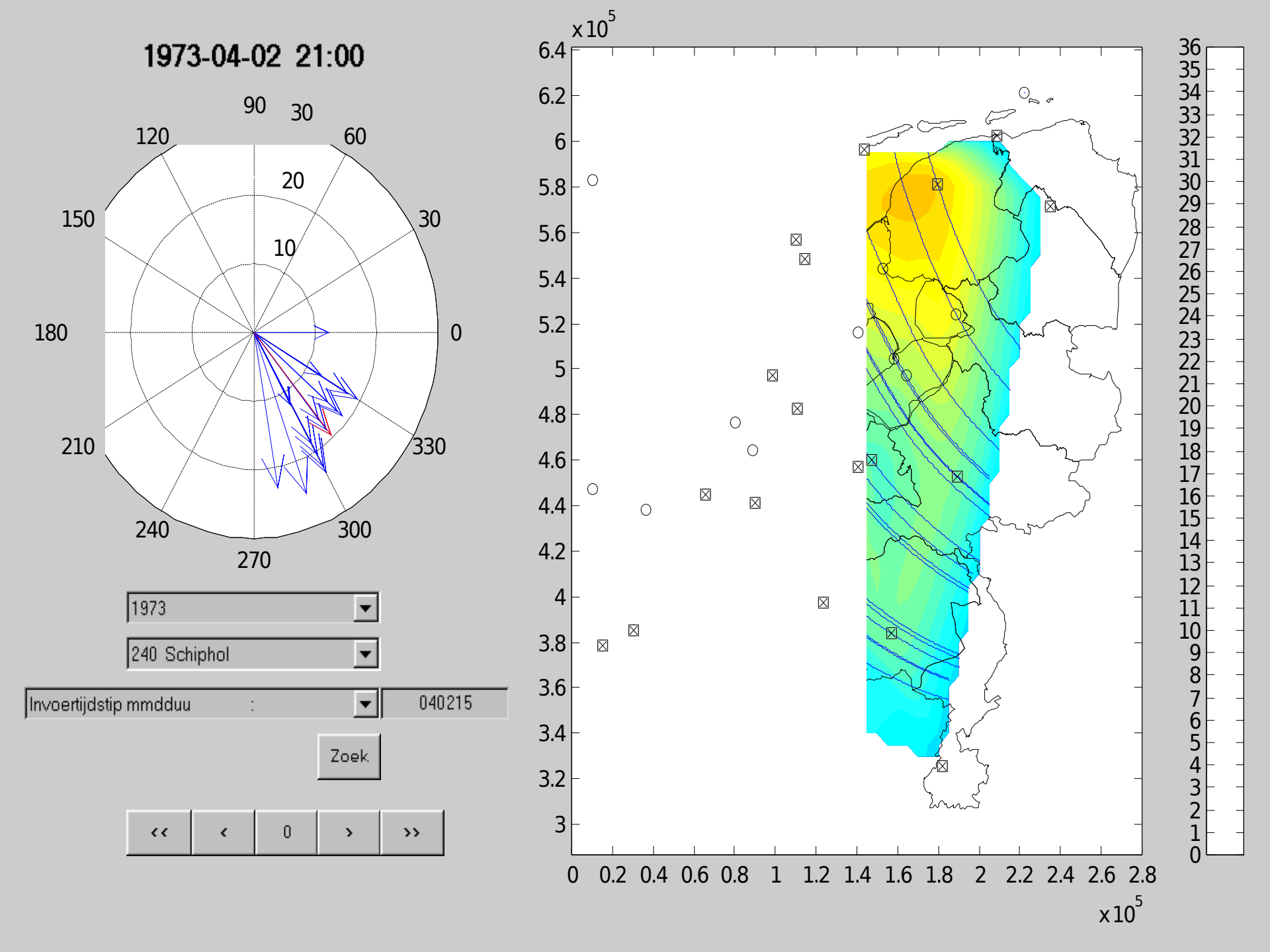
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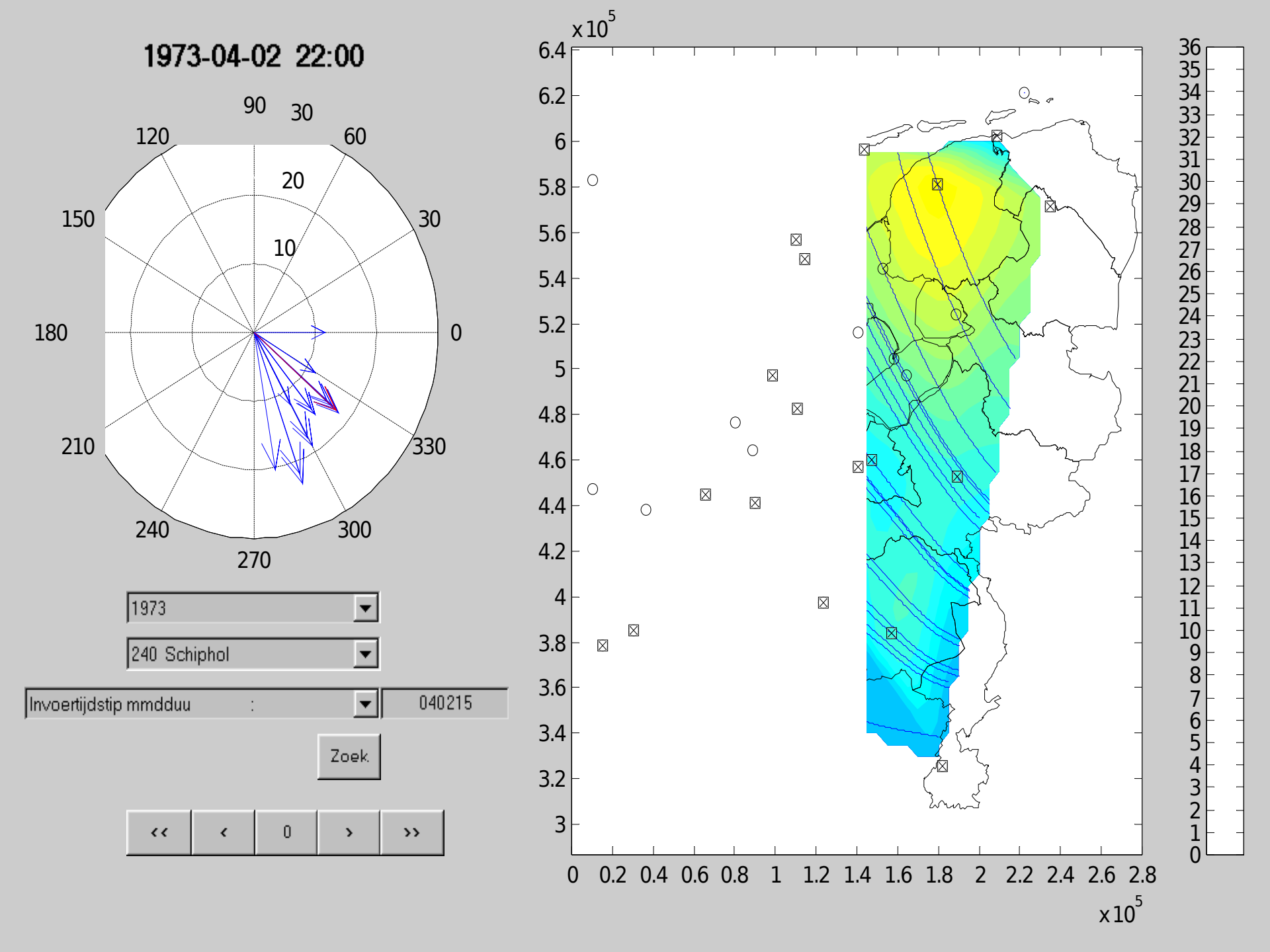
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Conclusions

1. Overview of basic design components
2. Even the basics show (major) problems:
   - interaction between wind, water levels and waves
   - wind transformation from land to water
   - air-sea interaction: wind drag
   - extreme value statistics of wind
3. And – of course – there is more:
   - variation is space: wind field
   - variation in time: wind field moves and changes
4. But:
   1. practical approaches are available
   2. cooperation in research may provide better solutions

Additional challenges

1. Wave model:
   - Wave growth limit in shallow water
   - Wave - current interaction
2. Probabilistic model:
   - Introduction of storm surge bariers into probabilistic model
   - How should we deal with model uncertainties?